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Vol. XXII—No. 3

JANUARY
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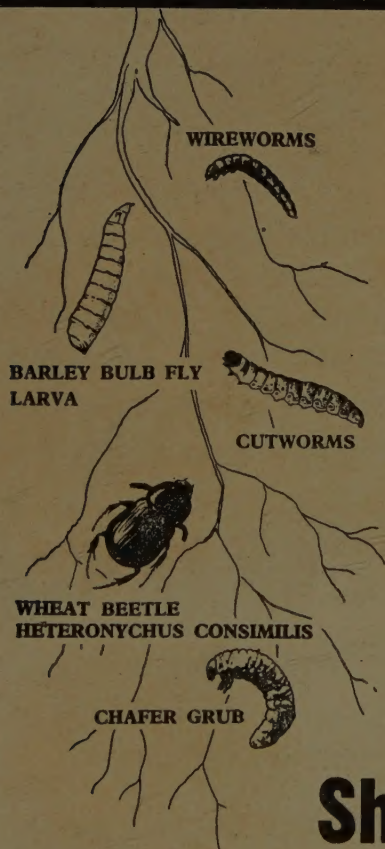
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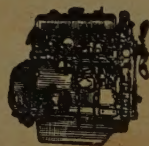
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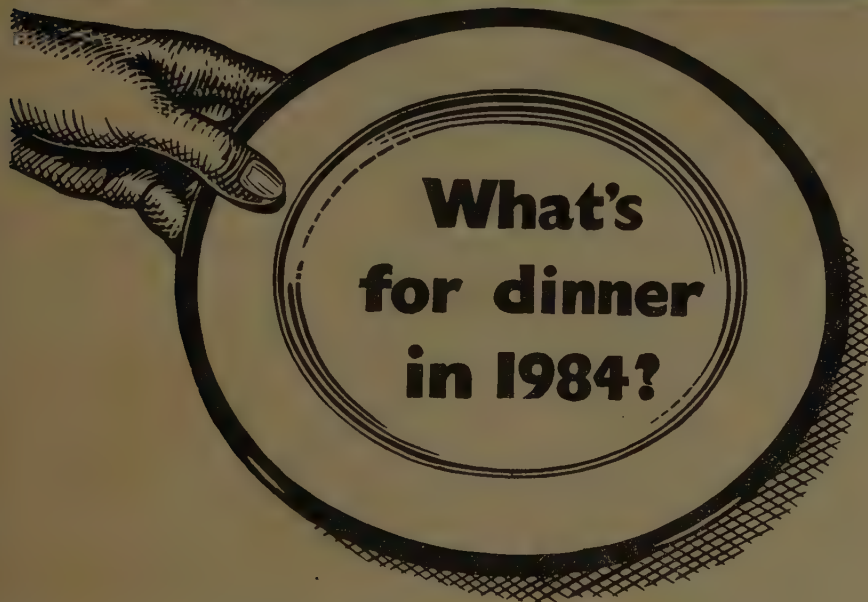
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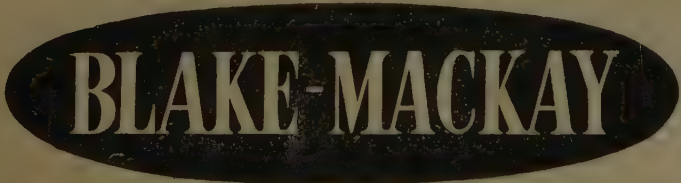
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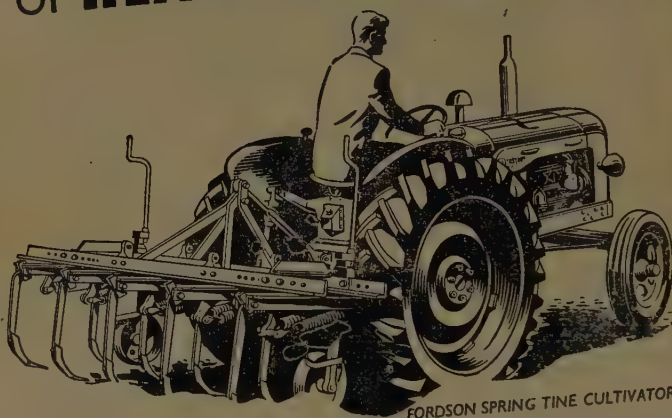


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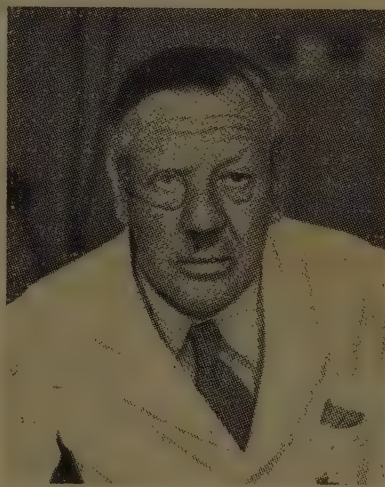
THE CONTRIBUTION OF V. A. BECKLEY TO AGRICULTURAL SCIENCE IN EAST AFRICA

Verey Alfred Beckley, O.B.E., M.C., M.A. (Cantab.), A.R.I.C., joined the Kenya Agricultural Department in 1924 as Agricultural Chemist. After 23 years in charge of the Chemical Section, he retired in 1947 but continued his chemical work as Scientific Adviser to the Pyrethrum Board of Kenya. Still later he was re-engaged by the Department as Senior Agricultural Chemist (Pyrethrum) in which position he remained almost until his death, his health failing over the last years.

It is doubtful if his great contribution to agriculture will ever be fully appreciated, since apart from his impressive contributions in many fields, which are indicated in the list of publications appended, it can never be known how greatly he influenced his colleagues and other agriculturalists. His encyclopædic knowledge on a wide range of subjects was always freely at the disposal of colleagues; and they benefited from this over the whole period of his service at the Scott Agricultural Laboratories, which extended altogether to 32 years.

On joining the Kenya Agricultural Department in 1924 he immediately started manurial experiments and soil analysis; this was followed by coffee fermentation studies, and later the possibility of obtaining power alcohol from sisal waste was examined. At Beckley's request the Entomologist, T. J. Anderson, obtained pyrethrum seed from England and this was planted at the Scott Laboratories. The late Mr. Gilbert Walker had the previous year obtained seed from Dalmatia and planted it at Nakuru. Early in 1930 Beckley prepared the first pyrethrum extracts from Kenya-grown flowers, which proved effective in the control of the *Lygus* and *Antestia* bugs of coffee. Following the demand by coffee planters for high-quality pyrethrum for the control of these insects, the widespread planting of pyrethrum took place, from seed supplied from the Scott Laboratories and Mr. Walker's plantation. The effective collaboration of Beckley and Gilbert Walker laid the foundation of the pyrethrum industry of Kenya. In 1929, again with Mr. Walker, essential oil plants and

seeds were imported, cultivated and extracted, and another agricultural industry started. Later they were to collaborate on the high-nicotine tobacco industry. These important subjects were only a part of his work for agriculture. No suggestion or problem put to him in connexion with the development of the Colony's agriculture ever failed to rouse his interest and effective help.



As early as 1930 he initiated the analyses of grasses, concentrates, and local feeding-stuffs. Soil conditions were studied in connexion with the nutritional requirements of crops, and methods of making compost to build up the soil fertility in the reserves. In 1932 he undertook the Kenya part in the preparation of Milne's Soil Map of East Africa, planned at the Conference of E.A. Soil Chemists at Amani. In 1933 surveys were made on the possibilities of irrigation in the Kamasia Njemps Reserve and soil work was carried out for the Sampson and Harris Tana River Irrigation Survey. Pyrethrum had by now become a most promising crop for higher altitudes and methods of analysis were studied. A study was also made of pyrethrum dryers, and of new essential oils. In 1935 he attended the 3rd International Soil Congress at Oxford. Soil surveys were continued in connexion with the Baringo and Perkerra Irrigation Scheme. A spectrographic apparatus was ordered for

studies that included possible deficiencies of the minor elements in coffee. In collaboration with the Senior Plant Breeder, a simple rapid method for assessing the quality of wheats was developed. In 1936 he continued studies of pyrethrum drying and undertook collaborative research with Dr. Gnadinger in the United States, to investigate the extent of deterioration of pyrethrum between Kenya and America.

The year 1937 saw the establishment of a guaranteed minimum pyrethrum content for Kenya pyrethrum flowers for export (namely, 1.3 per cent total pyrethrins) and in consequence large numbers of regulatory analyses had to be undertaken. The resulting interest in the methods of analysis created a great deal of investigation. This was only part of his work; in addition there was investigation on the retting of sisal flume tow, rates of decomposition and nitrification of green manures and heavy weed growth, interest in ramie fibre, appointment to the Sisal Research Joint Standing Committee, and the Pollution Committee of the Water Board. In 1938 the spectrograph was loaned to Amani, as, though he recognised that it was a "most valuable tool in the equipment of a chemical lab.", he had not the time nor staff to make full use of it.

When the Pyrethrum Board was formed he became adviser to the Board, and in 1939 he visited America on pyrethrum work. He returned on the outbreak of war and from then on, in spite of shortage of staff, chemicals and apparatus, he set to work. Pyrethrum analysis never stopped, though at one time chloroform, which was essential to the analysis, had to be made in the laboratories. In 1940 a dried vegetable factory was set up at Kerugoya and was in full production by August, 1941, largely due to his help in solving practical problems. Control analyses of products, including Vitamin C in the dried paprika produced for the army, were regularly carried out. As a collaborator and consultant in the development of war-time industries and the production of substitutes, his work and advice was invaluable. The range of products handled varied from production of cold-water waterproof glues to oils for lubricating fibres, from local production of chocolate to a search for a substitute for case hardening steel, soap, plasticine, floor polish, fishing nets, blackboard chalk; nothing seemed beyond his scope. As well as making investigation into the improvement of processing and packing of

dehydrated vegetables, he helped to organize rural industries, particularly spinning, weaving and tanning, and visited the United Kingdom for consultations on the vegetable factories. He was always interested in botanical subjects and his knowledge of plants was of great value.

The years 1946 and 1947 were difficult, with the return to peace-time work and with many staff changes. In December, 1947, he retired from Government Service, and became Scientific Adviser to the Pyrethrum Board of Kenya. He continued work at the Scott Laboratories, supervising the spectrophotometric analysis of pyrethrum that he had initiated, and doing much other pyrethrum work, including a study of pyrethrum powder for the control of grain weevils. In 1950, grading analysis services returned to Departmental control, and Beckley returned as Senior Agricultural Chemist (Pyrethrum). With periods of ill health intervening, he continued to work and to advise his colleagues up to the end.

The following tribute was paid by a colleague in his section: "His wide knowledge of all branches of science, his prodigious memory and his enthusiasms made him an inspiring person to work under". Many scientists to-day are of necessity so specialised that they can only do significant work in a restricted field. This memoir makes it clear that Beckley was not one of these, but a man of wide interests in the many subjects needed for the scientific study of agriculture. It was his exceptional ability both to carry out researches designed to enable him to give sound practical advice to farmers, and to probe the many aspects of a scientific problem put to him by a colleague and to bring his wide knowledge to help in its solution, that made such a great contribution to the advancement of agriculture in Kenya.

This is not the place for many personal details but I may recall that in their Departmental days the Beckleys' hospitable home was always open, especially to young people. Of their five children, Eve and Peter survive, their elder son Verey, a promising Agricultural Officer, having been killed in action against *Mau Mau*. It is not possible to end this memoir without mentioning his wife for her great support to him throughout his career and especially in his last years.

R. Le PELLEY

PUBLICATIONS BY V. A. BECKLEY

- 1929—
Utilization of Sisal Waste for the Production of Power Alcohol. *Dept. of Agric., Kenya, Bull.* 6.
Notes on the Silt Content of some Kenya Rivers. *Ibid.*, Bull. 7K.
A preliminary Note on the Fermentation of Coffee. *Ibid.*, Bull. 7M.
- 1930—
Soil Deterioration in Kenya. *Ibid.*, Bull. 4.
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The Yellowing of Coffee. *Ibid.*, Bull. 3.
Essential Oils. Methods of production and possibilities in Kenya. *Ibid.*, Bull. 19.
(with A. D. le P. Trench.)
Coffee growing in the Trans Nzoia. *Ibid.*, Bull.
Some Symptoms of Plant Nutrient Deficiencies in the Coffee Tree. *E. Afr. and Uganda J. Nat. Hist.*, 38 and 39, 10.
- 1932—
Some Factors in the Manuring of Coffee. *Dept. of Agric., Kenya, Bull.* 16.
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Stills for the production of Essential Oils. *Ibid.*, Bull. 25.
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Nitrates in the Soil and Root Development in Coffee. *Nature, Lond.*, 131, 878.
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Organic Manures, with special reference to Composts. *Dept. of Agric., Kenya, Bull.* 9.
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Soil Erosion. *Dept. of Agric., Kenya, Bull.* 1.
Coffee in Kenya. I. Chlorosis and Die-back in Coffee. *Emp. J. exp. Agric.*, 3, 203-9.
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Essential Oils. II. Oils from Indigenous Plants. *Ibid.*, 1, 469.
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Geranium Oil in Kenya. *Perfumery Essential Oil Record*, 28.
Notes on Manures and Manuring. *Coff. Board Bull. Kenya*, 3, No. 29.
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A PRELIMINARY NOTE ON THE BREEDING AND GROWTH OF TILAPIA IN MARINE FISH PONDS ON ZANZIBAR ISLAND

By F. H. Talbot and B. S. Newell, East African Marine Fisheries Research Organization

(Received for publication on 1st August, 1956)

The following notes describe an initial experiment in the stocking of marine fish ponds operated by the Organization with a species of wild *Tilapia* found in the estuarine reaches of the Mzinga Mzinga stream, at the north-western end of Zanzibar Island. This species had been collected twice previously from Zanzibar. It is closely allied to *Tilapia mossambica* (Peters) and to *Tilapia pangani* Lowe, being fairly similar to the latter but differing from it in the lateral line scale count. It is possibly a distinct species, and Dr. Trewavas of the British Museum is working on its systematic position.

The species is hardy, as is shown by its tolerance of widely varying environments. For instance, *Tilapia* fry were netted in the Mzinga Mzinga stream where the water was almost completely fresh, and where in places the oxygen content was very low—only about one quarter saturation. When transferred to the fish ponds, they successfully adapted themselves to water slightly saltier than the outside sea, and supersaturated with oxygen. The temperature difference between the two environments was about 12° C. (21° F.), and, whilst the fish pond water (like the open sea) is always alkaline, the stream water was slightly acid.

Two series of water samples were collected from the Mzinga Mzinga stream: the first series just before low water springs in February, 1956, and the second at about half-tide a month later a few hundred yards downstream from the earlier location. In each case the flow was seaward. Sampling at the pond was carried out in March, one day before the periodic "topping-up" that is effected twice a month at each high water spring tide. Salinity and temperature are here affected by rain, drainage from the surrounding land, evaporation and the prevailing meteorological conditions. At the time of sampling there had been no rain for two weeks and the sky was clear. As the atmospheric temperature in March is at its maximum for the year, the conditions of sampling probably represent the highest extremes of temperature and salinity to which *Tilapia* have so far been subjected.

The analyses of the stream and pond samples are given in the Appendix, Tables I, II, III and IV. Where a range of values is given (e.g. for oxygen in the Mzinga Mzinga stream) these are the limits of all samples, the bottles having been filled at random in various parts of the stream. So far no *Tilapia* have been caught at high tide; but this is more likely to be due to the physical difficulties of netting in deeper water than to the absence of the fishes.

THE EXPERIMENTAL POND

The fish ponds at Chukwani, some four miles from Zanzibar Town, are designed on the simple mud-walled system of the East, but with cement gateways, grooved to fit heavy wooden doors. Every spring tide the ponds are topped-up by placing a wire-netting sieve over the cement entrance on the flooding tide, and opening the doors until high tide.

The pond used for *Tilapia* is half an acre in extent, and normally 30 to 20 inches deep over most of the area at average filling, but with a deeper pool just inside the sill, and a deep ditch 18ft. by 60 ft., these providing cooler water and shade when the water level is low. The pool varies from 10 inches when all doors are removed to 40 inches in depth at average filling, and the ditch from 25 inches when all doors are removed to 55 inches at average filling. The water in the pond will be subject to considerable variation in properties, since, during the period of each two weeks prior to topping-up, its salinity, temperature and oxygen content will vary with meteorological conditions, especially over the course of the year as the seasons change. These changes can be expected to affect the flora and micro-fauna of the pond, which will themselves in turn affect such important factors as oxygen and nutrient salt content and pH. Furthermore, at each topping-up the pond suffers an influx of sea-water (itself varying in properties with the seasons) which has passed over a mangrove tidal flat. These conditions severely limit the number of species able to live and grow in the ponds. Of those species

normally found in the mangrove area, only the milkfish, *Chanos chanos* (Forsk.), and the *Tilapia* here discussed have shown suitable growth increases, although a number of food fishes, including the mullet *Mugil seheli*, are able to exist.

The bottom of the pond is normally covered with a spongy, dark green carpet, rich in filamentous algæ, diatoms, protozoa and bacteria. This is the productive layer. During a visit to Zanzibar Miss D. Ballantine of the Plymouth Marine Laboratory found that *Chaetomorpha* and *Lyngbya* formed the bulk of the filamentous algæ, with the former predominating. Of the unicellular algæ the Naviculoid diatom *Pleurosigma* is abundant, forming brown patches in the shallow water areas, and *Gymnodinium* is common. This algal carpet harbours a large population of small invertebrates, mainly ostracods and other small crustacea, but including worms, rotifers and gastropods. The large snail *Cerathidium* is common, crawling on the pond floor. Penaeid prawns are present, but not in large numbers. Of these *Metapæneus monocerus* (Fabricius) and *Penæus monodon* have been identified.

Of the 22 species of fishes normally found in a pond when it has been open to the sea, eight are present only in the juvenile stages as noted in the Table below:—

TABLE I

<i>Elops saurus</i> Linnaeus ..	rare	juveniles only
<i>Chanos chanos</i> (Forsk.) ..	abundant	juveniles only
<i>Syngnathus spicifer</i> Ruppell	present	
<i>Therapon jarbua</i> (Forsk.)	present	
<i>Promicrops lanceolatus</i> (Bloch) ..	rare	juveniles only
<i>Sillago</i> sp. ..	rare	
<i>Caranx ignobilis</i> (Forsk.)	rare	juveniles only
<i>Caranx sexfasciatus elacate</i> Jordan & Everman ..	rare	juveniles only
<i>Monodactylus argenteus</i> (Linnaeus) ..	common	
<i>Gerres punctatus</i> Cuvier ..	common	
<i>Gerres oyena</i> (Forsk.) ..	common	
<i>Ambassis safgha</i> (Forsk.)	common	
<i>Lutianus argenteimaculatus</i> (Forsk.) ..	present	juveniles only
<i>Lutianus ehrenbergi</i> (Peters)	rare	
<i>Lutianus sanguineus</i> (Cuvier & Valenciennes) ..	rare	juveniles only
<i>Lutianus fulviflamma</i> (Forsk.)	present	
<i>Mugil seheli</i> Forskal ..	abundant	
<i>Atherina</i> sp. ..		
<i>Sphyræna commersoni</i> Cuvier & Valenciennes ..	common	juveniles only
<i>Gobius</i> sp. ..	abundant	
<i>Periophthalmus</i> sp. ..	abundant	
<i>Platycephalus indicus</i> (Linnaeus) ..	rare	

It seems typical of many marine fish that their juveniles are found over a wider range of habitats than their adults and are more tolerant of changes in their physical and biotic environment. This has been demonstrated in fish populations in the Tamar Estuary (Hartley 1940), in brackish lagoons along the Gold Coast (Irvine 1947), and in the Klein River Estuary (Talbot 1954). An example of this is *Lutianus sanguineus*, whose juveniles may occur in the fish ponds, but whose adults are never found near mangrove areas, being typical of deeper waters, and taken in 40 fathoms off the southern tip of Zanzibar Island. Similarly adult *Caranx ignobilis* is a predator of coral areas, not found in mangrove swamps.

Of the species listed, *Chanos chanos*, the milkfish, shows a very high growth rate and, as in the East, is a most suitable stocking species from this point of view; but it does not breed under fish-pond conditions and great difficulty has been found in obtaining regular or adequate supplies of fry or fingerlings. This species feeds on the algal surface layer of the bottom, in competition with *Tilapia*.

TILAPIA STOCKING

Before transfer to the Chukwani pond, the *Tilapia* were "acclimatized" in the laboratory by keeping them in an aquarium tank to which salt was gradually added. Direct transference from the stream to the pond resulted in death of the fish, so that although this species of *Tilapia* shows remarkable adaptation to environment it is evident that the adaptation is gradual.

Prior to stocking with *Tilapia* the pond had been left dry for two months, being filled two weeks before the first fish were introduced. Three hundred and one juvenile *Tilapia* were introduced in eight small lots from the 31st October to the 30th December, 1955. A measured sample of the stocked fish gave an average weight of 0.25 oz., the fish varying from 40 to 80 mm. standard length (length without tail).

After six months the pond was reaped by rotenone poisoning and netting. 248 *Tilapia* were removed, whose length-frequency distribution (Fig. 1) suggests that the original stocking had bred twice during this period. The original stocking (Group I, Fig. 1) were all mature, but neither Group I nor Group II had reached maturity. The fish had therefore matured at between 90 and 120 mm. The distinct and separate modes suggest that all

the fish bred at two sharply defined periods. This was also borne out by observations, as one of the authors noted breeding behaviour on one visit to the fish ponds but no such behaviour on subsequent visits.

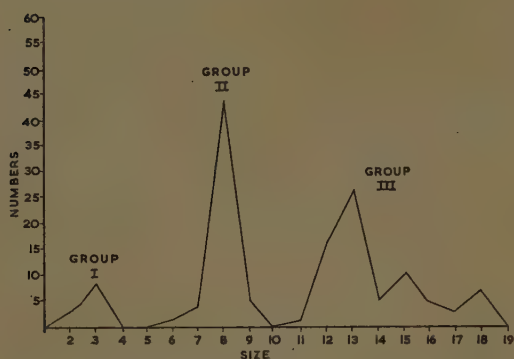


Fig. 1.—Length-frequency curve for *Tilapia* from Chukwani fish pond, showing the three distinct size groups. Length in centimetres

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Of the original stocking 27 per cent had survived and the largest fishes had reached $\frac{1}{2}$ lb. in weight.



Fig. 2.—Part of the catch of *Tilapia*, Group III

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Stomachs of *Tilapia* from the pond showed that they were feeding on the algal bottom layer, taking little or no filamentous algæ, green or blue, but much unicellular algæ and bottom detritus, the latter containing decayed pieces of larger plants. In spite of the presence in this layer of small invertebrates, these were not found in the *Tilapia* stomachs.

The ease of breeding under fish-pond conditions shows that a supply of juvenile fish for stocking should present no problems. Indeed, it is probable that, to prevent a high rate of breeding and stunted growth in a stocked pond, either the monosex type of culture or the method suggested by Hickling (1951) of vigorous cropping and thinning out of the younger fish at monthly intervals should be used.

COMPETITION FROM *Chanos chanos*

In spite of attempts to keep out extraneous fish by the use of wire mesh during pond filling, a number of species enter the ponds either through lack of care by fish-pond staff or the presence in the fish-pond area of fry small enough to enter through the mesh screens. Of these species the only one that enters the Zanzibar ponds in any quantity is the milkfish, in some years in negligible amounts, but in 1956 in large numbers. When the *Tilapia* pond was reaped in July, 1956, one hundred and five pounds of milkfish were taken, fish that had been in direct competition with *Tilapia* for food. Although in the present case the low stocking rate of *Tilapia* prevented overgrazing when the milkfish entered, the numbers of milkfish in the pond area are so variable that this species cannot be used as a natural and easy method of stocking or part stocking the ponds.

Tilapia do not succumb as easily to rotenone poisoning as the milkfish and other pond species. Addition of rotenone on the 12th July killed less than one-third of the total population of *Tilapia*, but completely destroyed the large numbers of milkfish and the small populations of other fish, including *Gerres punctatus*, *G. oyena*, *Therapon jarbua*, *Mugil seheli*, *Elops saurus*, *Atherina* sp., and *Lutianus fulviflamma*. Netting the following day showed that two-thirds of the *Tilapia* had survived. Further poisoning with a greater concentration of rotenone brought no more fish to light. Laboratory tests on the effects of rotenone on *Tilapia* and *Mugil seheli* in an aquarium tank tend to suggest that the *Tilapia* resist the poison longer than the *Mugil seheli*. The latter dies almost immediately on the addition of a very small concentration of rotenone emulsion, whilst some *Tilapia* survived after 20 minutes, eventually succumbing after about half-an-hour's exposure. It was observed that the emulsion tends to remain near the surface, despite the use of a wetting agent, and vigorous

stirring is necessary to disperse it. After stirring, the emulsion descends and the fish can be seen to react to this descending "barrier", immediately diving to the bottom as they encounter it. It is the normal behaviour of *Tilapia* to dive to the bottom of the pond when disturbed, and in this way many of them may escape the poison. Further tests will be carried out in the laboratory when supplies of fish are available from the pond, to establish the minimal concentration of rotenone necessary for lethal effect on various species of fish. It would seem that it may be possible to "clean" the pond of all species of fish other than *Tilapia* by judicious use of the rotenone poison.

The rotenone used was in the form of "Staff Allens" Rotenex resin, containing 25 per cent rotenone. This is dissolved in warm xylene and one volume of this solution is added to an equal volume of emulsifying agent. The latter consists of a 50:50 mixture of solutions of "Manoxol O.T." (Hardman & Holden Ltd., Manchester) and "Ethylan C.P." (Lankro Chemicals Ltd., Manchester). These materials were obtained through the courtesy of the Zanzibar Government Entomologist, Dr. F. L. Vanderplank.

For help with identifications our thanks are due to Dr. Ethelwyn Trewavas (*Tilapia*), Dr. Isabella Gordon (Crustacea), Miss D. Ballantine (Algæ), Mr. F. Williams (Carangidae and Sphyraenidae) and Mr. J. F. C. Morgans (Seranidae).

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APPENDIX

TABLE I

Water samples collected from the Mzingu-Mzingu stream at 10.30 hrs. on 13th February, 1956 (low water springs 11.11 hrs.). A slow but steady flow seawards was observed. Sandy bed with no black mud or deposit visible. Greatest depth of water about

1½ ft. High banks densely vegetated, hindering wind access. Water cloudy:—

Temperature—26.2° C.

pH—6.7/6.8.

Oxygen { 1.6 to 2.65 mils/litre.
27% to 45% saturation at 26.2° C.

Alkalinity { Bound CO₂ 1.12 millimols/litre.
Total CO₂ 2.15 millimols/litre.

Total solids { Organic matter 0.237 grams/litre.
Mineral residue 0.867 grams/litre.
Silver nitrate titre 0.8 to 1.0 p.p. mille.

Calcium { Total—60 milligrams/litre.
Dissolved—40 milligrams/litre.

Phosphate—Negligible (less than 2 micro-gram atoms P/litre).

Ammonia—Negligible (less than .04 p.p.m.).

TABLE II

Water samples collected from the Mzingu Mzingu stream at 09.00 hrs. on 16th March, 1956 (high water springs 06.10 hrs.). The site visited was a ford a few hundred yards downstream from that used in February. A strong current seawards was observed, and shoals of small mullet and a few large prawns were seen. Greatest depth of water, 3 ft.

Temperature—28.1° C.

Oxygen { 2.6 to 2.8 mils/litre.
49% to 53% saturation at 28.1° C. and
chlorinity 8.5 p.p.mille.

pH—7.5/7.9.

Salinity—15.5 p.p.mille (Silver nitrate titre).

TABLE III

Water samples were collected from Chukwani main pond on 12th March, 1956, the bottles being filled from the sump adjacent to the gates one day before the periodic topping-up.

Temperature { Sump—37° C.
Periphery 38° C.

pH { Surface—8.4 (in situ; all corrections applied
Bottom—8.4 for salinity and temperature.)

Oxygen { Surface 4.7 mils/litre (117.5% saturation).
Bottom 3.3 mils/litre (82.5% saturation).

Salinity—35.10 p.p.mille (Silver nitrate titre).

Phosphate—0.25 micro-gram atoms P/litre.

TABLE IV

Figures for surface water in the open sea off Zanzibar at this time of the year are as follows:—

Temperature—29.35° C.

pH—8.49.

Oxygen—4.4 mils/litre (97% saturation).

Salinity—34.8 p.p.mille.

Phosphate—0.5 micro-gram atoms P/litre.

Methods of analysis will be described in a subsequent publication, together with results of a histological examination of *Tilapia* kidneys and further biometric data on this fish.

THE INFLUENCE OF FERTILIZERS ON PINEAPPLE REPLANT AREAS

By H. R. Evans, Department of Agriculture, Kenya

(Received for publication on 5th July, 1956)

Experience in Kenya has shown that, when pineapples are replanted immediately following a previous cycle under this crop and without the addition of fertilizers, the replant crop often fails. This experience is in common with that of most other pineapple-producing countries of the world. Though crop rotation appears to offer a solution, knowledge of the form that this should take is lacking. While steps have been taken to acquire this knowledge, the rapid expansion of the pineapple industry necessitated an interim answer to ensure the productivity of replant crops.

As there have been no really serious nutritional problems with pineapples grown on virgin soils in Kenya, the trial discussed in this paper, which was initiated by Mr. T. H. Jackson, Senior Horticultural Officer, was concerned solely with the problem of the response of pineapples to various fertilizer treatments where one cycle of pineapples was immediately followed by another on the same land.

Since good results have been achieved with sulphate of ammonia in Hawaii and Australia, it was decided to lay down a field trial to investigate the influence of nitrogen in this form on Smooth Cayenne pineapples. Pineapples on replant soils often develop yellowish foliage which has been thought to be associated with an iron and/or magnesium deficiency; and it was accordingly decided to include treatments with these two plant nutrients at the same time. In Hawaii, it has been found that soil fumigation stimulates pineapple growth whether nematodes are present or not. Consequently, a soil fumigant, ethylene dibromide, was also included.

Pineapple growing in the European farming areas has recently been taken up by coffee planters amongst others. Since coffee requires the best of the red soils, with Napier Grass (*Pennisetum purpureum*) grown to produce mulch for the coffee often taking second place, the type of land left for the pineapple crop is frequently poorly drained, shallow, red

to light brown clay-loam soil, often containing much "murrum" in the profile. It was therefore to be expected that some form of fertilization would prove beneficial for the economic production of pineapples where continuous cropping is practised.

CLIMATE AND SOILS

The trial was carried out in the Central Province, at Karimaini Estate, Thika, which is the present centre of the pineapple-growing industry. The altitude of the estate is 5,300 feet and the average annual rainfall for the period of the trial was:—

April to December, 1951	47.41 inches
January to December, 1952	29.08 inches
January to December, 1953	23.98 inches
January to December, 1954	40.40 inches
January to July, 1955	18.40 inches

Mean temperatures over the same period ranged from a maximum of 75.9° F. to a minimum of 55.0° F.

The soil type on which this trial was established was a shallow, grey-to-brownish loam over murrum to almost pure murrum soil. This is a typical example of the soil in this particular area that is now being cropped to pineapples. The topsoil (0-6 inches) pH was 5.99. (The pH was determined with a glass electrode on a 1:2.5, soil: water suspension.)

EXPERIMENTAL DETAILS

The trial was planted in April, 1951, during the long-rains season. The design was an unconfounded 2⁴ factorial with four replications. The plot size was 30 plants in three-row beds at a spacing of 1 ft. between the plants, 2 ft. between the rows and 9 ft. between the beds.* Fruit crowns were used as planting material. Treatments were 0 and 2,000 lb. of sulphate of ammonia per acre, 0 and 56 lb. of magnesium sulphate per acre, 0 and 67 lb. iron (ferrous) sulphate per acre, 0 and 8 gallons of ethylene dibromide soil fumigant per acre.

* This spacing accommodated 10,000 plants per acre. The standard present-day spacing of 1 ft. between plants, 2 ft. between rows with 3 ft. between the 2-row beds, accommodates approximately 17,000 plants per acre. This results in much higher yields than the now obsolete spacing used in the trial.

All the treatments, except ethylene dibromide, were commenced in December, 1951, and the methods of application were as follows:—

- (1) Sulphate of ammonia was applied in four applications at the rate of 500 lb. per acre at bi-monthly intervals, placed in the base leaves of the plants.
- (2) Magnesium sulphate and iron sulphate were both applied as foliage sprays at 2 per cent concentration. Applications were made five and six times respectively at monthly intervals.
- (3) Ethylene dibromide was applied once in May, 1952, at a 10 per cent concentration. Application was by means of a hand injector, injections being made at intervals of nine inches along either side of the central row and also on the outside of the outside rows, within six inches of the plants and to a depth of six inches for each injection.

Crop recording was carried out as the fruit became ripe, each fruit being weighed separately. After the plant crop had been harvested, shoot production was restricted to a single sucker to encourage the production of a good first-ratoon crop of high-grade fruits. Weeding in the rows was done by hand, but between the beds weeds were controlled mechanically with a disc harrow.

RESULTS

The time taken to produce the plant crop, from planting to final harvest, was 30 months and the first fruits were picked 22 months after planting. The time taken to produce the first ratoon crop from the final harvest of the plant crop to the final harvest of the first ratoon crop was 21 months.

The summary of results presented as Table I shows the value of the nitrogen applications and the depressing effect of the soil fumigant. It also shows the residual influence of nitrogen on the first ratoon crop and the continued suppressing influence of ethylene dibromide.

Table II shows the calculated effects of treatments that were statistically significant. The effect of sulphate of ammonia was to increase significantly the total yield per acre, by reason of the increased number of plants which bore fruit and also by raising the mean fruit weight. The significant increase in mean fruit weight was confined to the plant crop, but the overall effect for the plant crop plus

the ratoon crop was significant as well. Thus the greatest effect on mean fruit weight from the sulphate of ammonia application occurred in the crop to which the application was made.

The effect on yield of the soil fumigant was to decrease very significantly the mean fruit weight and the number of fruits per acre averaged over the two crops. However, this treatment did not significantly decrease the mean fruit weight of the plant crop and this effect was only recorded for the ratoon crop.

The magnesium treatment significantly increased the mean fruit weight of the ratoon crop and the overall effect was still significant for the average of the plant plus the ratoon crop.

The effect of nitrogen in the presence of the soil fumigant significantly increased the number of fruits harvested per acre. Iron in the presence of the soil fumigant significantly increased the yield per acre in the plant crop and the number of fruit per acre. The combination also showed a significant average overall increase in the yield per acre of the plant crop plus the ratoon crop.

Figure 1 shows the more important results of the single factor treatments in terms of the percentage of fruits weighing 4 lb. and over, and emphasizes the significant influence of nitrogen for the production of fruits over this weight. Although ethylene dibromide suppressed yields and mean fruit weight, the percentage of fruits of 4 lb. and over was not significantly affected. Iron had no significant influence whatever, but magnesium significantly increased the percentage of fruit over 4 lb. in weight.

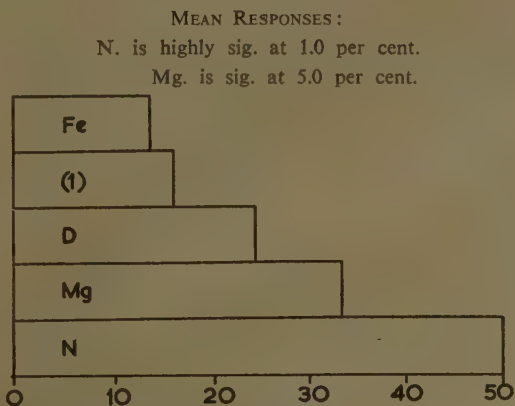


Fig. 1.—Mean percentage of fruits of 4 lb. and over from plant and ratoon crops

Figure 2 shows the cumulative percentage of fruit harvested month by month for the control, nitrogen and ethylene dibromide treatments. In both crops, nitrogen accelerated fruiting during the first four months of the harvest and also induced fruiting during months when no fruits were produced by the nil treatment. More than half the plant-crop fruits were harvested during the period prior to the cold season, i.e. from July to September, thus minimizing fruit losses that often occur during these months when "Black Spot" disease* is most prevalent.

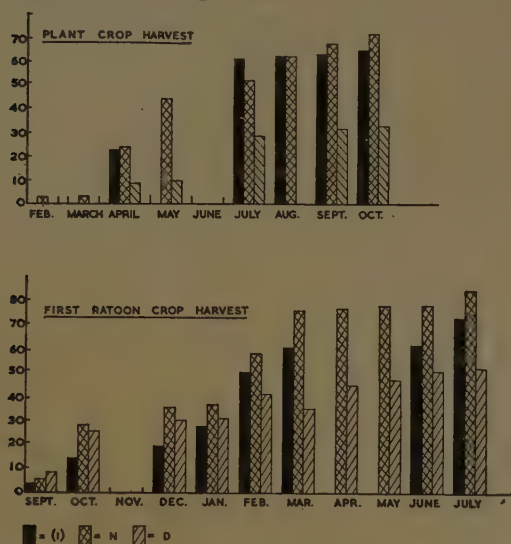


Fig. 2.—Cumulative percentages of fruits harvested month by month for the plant and ratoon crops

The peak harvest periods for the plant crop were April and July for the nil treatment, while April and May were the peak periods for the nitrogen treatments. The May peak for the nitrogen was less pronounced than the nil-treatment July peak. The ratoon harvests produced a more even maturing of fruit each month over a lengthier harvesting period than was produced by the plant crop. The respective harvesting periods were nine months for the plant crop and 11 months for the ratoon crop.

DISCUSSION

As nitrogen was not applied until eight months after planting, it is quite possible that a higher percentage of plants might have been induced to produce fruit had it been done sooner, thus improving plant vigour at a time when the young plants were establishing them-

selves. The visual response to the sulphate of ammonia could be clearly seen one month after treatment, in the improved green colour of the foliage.

Though a 2,000-lb. per acre level of sulphate of ammonia has enabled a heavier yield of pineapples to be taken from a replanted area than would normally be produced without fertilizers, further investigations are required to determine more accurately the optimum level necessary to produce an economic return.

The fact that nitrogen is capable of accelerating fruiting during the early harvesting period (Fig. 2) is an especially significant feature of the plant-crop results. During seasons of heavy rainfall, followed by overcast cold weather, a considerable number of the late fruits maturing between July and September can be lost from "Black Spot" disease, often prevalent at this time. By the acceleration of fruiting, losses from "Black Spot" may therefore be reduced.

The overall percentages of the plants that produced fruit were 69.5 per cent and 80 per cent for the plant and ratoon crops respectively. The number of fruits produced was higher for the ratoon crop than the plant crop. The greatest effect of the nitrogen on mean fruit weight was in the crop to which it was applied, i.e. the plant crop. No significant effect was recorded for the ratoon crop; but the effect over both crops considered together was highly significant. Thus residual nitrogen had a much lesser effect on the mean fruit weight, which might possibly have been increased to some degree by reapplication of sulphate of ammonia to the ratoon crop.

The fact that yields per acre in the first ratoon crop were equal to those of the plant crop in both the nil and the nitrogen treatments was attributed, to a large degree, to non-producing plants of the plant crop coming into fruit during the first ratoon-crop season. A 20 per cent loss of fruit as a result of plants failing to produce fruit is considered to be quite substantial, especially in view of the fact that field observations indicate that fruit crowns produce a more uniform field stand than other types of planting material. Fruit production results have therefore indicated a need to investigate not only the best type of planting material to use, but also the quality of that material, if uniform and high-producing stands are to be established. Hormones, as

* This disease takes the form of the "Black Spot" disease in South Africa as described by E. F. Malan, *Farming in South Africa*, 29, 258, 1954.

a means of flower induction, may be of even greater assistance in producing a higher percentage of fruits.

The results of ethylene dibromide injection are not considered conclusive. The time of application was probably unfavourable, because the plants were over a year old when the treatment was applied, and a considerable set-back occurred. The root systems would, by that time, have almost reached maturity, and consequently the deleterious effect of the ethylene dibromide on the feeder roots was reflected in the suppressing effect this treatment had on yields. Further investigations are required with this chemical before any conclusive results can be achieved.

The iron treatment, apart from increasing the number of fruits produced during the ratoon crop, had no favourable significance on either yields per acre or mean fruit weight. Magnesium had a significant effect on mean fruit weight though no significant increase in yield per acre was recorded.

The fact that the interaction of nitrogen and the soil-fumigant treatments was positive, in that the effect of this combination caused an overall significant increase in the number of fruits harvested per acre, would seem to indicate that ethylene dibromide may be useful if applied earlier than it was in this trial, but that, used without heavy applications of nitrogen, it may still have the effect of suppressing yield. A significant interaction between the iron and soil-fumigant treatment in terms of yield per acre was also recorded. It would seem, therefore, that any of the treatments which favourably interacted with ethylene dibromide probably did so by improving the nutritional conditions of the plants after root damage caused by the fumigant.

The interaction of the iron, magnesium and ethylene dibromide treatments produced a favourable response in the ratoon crop on yield per acre, fruit weight and number of fruits per acre. The average yield over the two crops was significantly increased; but it is considered that this reaction is of little practical importance at this stage of the investigations.

The increase in pineapple yields from sulphate of ammonia, at the rate of 2,000 lb. per acre, is economically significant. The cost of the sulphate of ammonia per acre was Sh. 635/60 gross and the price paid to the growers by the canneries was Sh. 200 per ton. The plant crop yield increase resulting from the nitrogen treatment was 3.9 tons per acre;

the cash value of which was Sh. 780. A gross profit of Sh. 144/40 per acre therefore resulted. At first sight this small profit would appear negligible. The residual effect of the sulphate of ammonia, however, was highly significant, resulting in a further increased ratoon crop of 2.38 tons per acre. The total gross profit per acre from the two crops was therefore Sh. 696/54. The canning price to growers during the first ratoon crop was based on fruit size and the average estimated price per ton from this crop was Sh. 232. Prices based on fruit size again emphasize the value of nitrogen, which produced such a high proportion of fruits of 4 lb. and over as compared with the nil treatment.

ACKNOWLEDGMENTS

I express my thanks to Mr. C. W. P. Harris, of Karimaini Estate, Thika, for his co-operation. I am also greatly indebted to Mr. J. B. D. Robinson (Agricultural Chemist, Kenya Coffee Services) not only for the statistical interpretation of the results of this trial but also for his helpful suggestions and criticisms during the preparation of this paper.

SUMMARY

Nitrogen, in the form of sulphate of ammonia at the rate of 2,000 lb. per acre, enables substantially increased yields of pineapples to be produced from the plant and first ratoon crops grown on land where one crop cycle is immediately followed by another. This fertilizer also accelerates fruiting during the early months of the fruiting season, thus reducing loss of crop as a result of "Black Spot" disease, which may occur in the later harvesting period from July to September. It increases plant vigour and results in a larger number of plants producing fruit. The overall mean fruit weight is also increased.

Post-planting soil fumigation with ethylene dibromide at a 10 per cent concentration, one year after planting, can destroy plants and cause a serious suppression of fruiting. When used with sulphate of ammonia at 2,000 lb. per acre, a favourable positive interaction occurred though fruit suppression was still evident in this experiment.

Iron and magnesium sprays at 2 per cent concentration did not produce any significant increase in yields, but magnesium increased significantly the mean fruit weight. When iron was combined with ethylene dibromide a significant yield increase was recorded.

TABLE I—SUMMARY OF RESULTS
MEAN TREATMENT YIELDS (Mean of 4 replicates for Plant and Ratoon data)

Treatments	PLANT CROP			FIRST RATOON CROP			AVERAGE OVER TWO CROPS		
	A	B	C	A	B	C	A	B	C
	(Means of 8 plots)								
(I)	10.1	3.31	6,666	10.8	3.22	7,326	10.5	3.27	6,993
N.	13.7	4.03	7,499	13.9	3.51	8,658	13.8	3.80	8,059
D.	5.5	3.12	3,833	8.1	3.40	5,328	6.8	3.26	4,629
Fe	10.3	3.22	7,066	12.1	3.35	7,992	11.2	3.29	7,626
Mg.	10.3	3.47	6,566	14.7	3.65	8,991	12.5	3.56	7,859
ND	10.9	3.92	6,233	12.5	3.22	7,992	11.7	3.57	7,160
NFe	12.9	4.21	6,833	14.9	3.32	9,657	13.9	3.77	8,325
NMg	12.4	3.92	7,066	12.1	3.37	7,992	12.2	3.65	7,493
DFe	6.2	3.26	4,166	7.7	2.77	5,328	7.0	2.98	4,795
DMg	7.0	3.49	4,399	7.5	3.17	4,662	7.2	3.33	4,629
FeMg	7.2	3.27	4,666	12.7	3.75	7,659	10.0	3.51	6,161
NDFe	13.2	4.28	7,499	11.4	2.92	8,325	12.3	3.60	7,992
NDMg	9.6	3.77	5,566	9.7	3.05	6,660	9.6	3.41	6,194
NFeMg	11.3	4.03	6,233	13.9	3.35	8,991	12.6	3.69	7,659
DFeMg	7.6	3.33	4,899	11.6	3.37	6,993	9.6	3.35	5,994
NDFeMg	12.1	4.34	6,566	14.4	3.67	8,658	13.3	4.01	7,659
L.S.D. 5%	3.4	0.54	2,065	3.5	0.46	2,091	2.9	0.33	1,811
1%	4.6	0.56	2,764	4.7	0.62	2,294	3.9	0.44	2,418

A=Yields. Tons per acre.

B=Average fruit weight. lb.

C=Number of fruits per acre.

(I)=Nil treatment.

N=Nitrogen.

D=Ethylene dibromide.

Fe=Iron.

Mg=Magnesium.

TABLE II—SIGNIFICANT TREATMENT EFFECTS

Treatments	PLANT CROP			FIRST RATOON CROP			AVERAGE OVER TWO CROPS		
	A	B	C	A	B	C	A	B	C
N.	+3.90	+0.75	+1,404	+2.20	—	+1,571	+3.10	+0.37	+1,489
D.	-2.00	—	-1,179	-2.76	-0.26	-1,613	-2.38	-0.13	-1,392
Fe.	—	—	—	—	—	+780	—	—	—
Mg.	—	—	—	—	+0.21	—	—	+0.12	—
N×D.	—	—	+738	—	—	+780	—	—	+759
Fe×D.	+1.40	—	+762	—	—	—	+1.02	—	—
N×Mg.	—	—	—	-1.33	—	—	—	—	—
Mg×Fe.	—	—	—	—	+0.25	—	—	—	—
N×D×Fe.	—	—	—	—	+0.17	—	—	—	—
D×Fe×Mg.	—	—	—	+1.60	+0.20	+760	+1.02	—	—
L.S.D. 5%	1.22	0.19	724	1.25	0.16	736	1.02	0.12	643
1%	1.62	0.26	967	1.67	0.22	986	1.36	0.16	859
Plant Crop									
Season ..	10.00	3.69	5,994	† Significant at 1% level. * Significant at 5% level.					
versus									
Ratoon Crop	†11.76	*3.32	†7,659						
L.S.D. 5%	0.69	0.19	269						
1%	0.93	0.44	359						

A=Yields. Tons per acre.

B=Average fruit weight. lb.

C=Number of fruits per acre.

NOTES ON ANIMAL DISEASES

XIX—MASTITIS IN CATTLE*

Compiled by the Department of Veterinary Services, Kenya

(Received for publication on 10th September, 1956)

Mastitis or mammitis is the general name applied to inflammation of the udder; it must be realized that the name does not indicate any specific condition. Most forms of mastitis are difficult to control and the condition is responsible for great losses every year in all dairying countries. As the economic importance of the individual dairy cow rises more and more in Kenya, so will the significance of this condition.

Cause.—Mastitis may originate in a number of ways:—

- (a) Localization of germs in the udder, following septicaemia caused by retained afterbirth and septic metritis. This is an important factor in acute mastitis in England.
- (b) Trauma or damage is definitely a predisposing factor in mastitis. The teat canal is normally a true barrier; but injuries, however slight, interfere and allow the entry of pathogenic organisms. In addition to this, direct wounds, e.g. tears in the skin from barbed wire, may allow entry of bacteria; or interference with a teat duct, e.g. with a dirty teat siphon, may provide a mode of entry.
- (c) Contagion. An example of this is chronic contagious streptococcal mastitis, probably spread from cow to cow on the hands of the milker, or by means of dirty teat cups with milking machines, or insufficiently disinfected udder washing-cloths.

In addition, bad methods of drying-off, changes in food and chills are often blamed as originating factors in cases of acute infection. It should be realised that the milking machine can be one of the major causes of trouble in a dairy herd, if it is not run efficiently. If such machines are run at too great a vacuum, certain cows may develop hardening of the udder, similar to that occurring in tuberculosis. In such cases the nature of the milk secretion is practically unaffected and

bacteriological examination would show absence of any infective process.

Mastitis is more prevalent in high-producing animals. It is reasonable to believe that, when a cow becomes a milk producing machine and no attention is paid to stamina, susceptibility to other troubles will be increased.

Symptoms.—Mastitis can be classified according to the reaction, i.e. acute, sub-acute, chronic or sub-clinical.

In acute mastitis one or more quarters of the udder may be infected. The affected part is swollen, hot and painful, and on drawing the teat a small quantity of serous fluid, clotted material or pus may be obtained. Many cases, if left unattended, will progress to gangrene, especially if *Corynebacterium pyogenes* is present. In sub-acute mastitis, possibly only one quarter is affected and the symptoms are less severe than those mentioned above. In chronic cases there is usually at the outset some hardening of the affected quarter before there is any visible alteration in the milk. In tuberculous mastitis, fortunately very rare in Kenya, before the character of the secretion becomes altered this hardening or induration may be extensive. In addition, the small glands high up above the rear of the udder may be affected and can often be felt on palpation. In chronic streptococcal mastitis, perhaps the only evidence that will arise is a reduced quantity of milk secreted by the quarter; and infection in such cases can only be confirmed by chemical or bacteriological tests. In sub-clinical mastitis, there may be no symptoms of any kind apart from a small amount of clot in the milk, if the latter is specifically examined for such abnormality, e.g. by means of the strip cup.

In addition to local symptoms there may be general disturbance in severe cases. Examples are fever, lack of appetite and, in the later stages, signs of toxæmia or septicaemia.

Except when gangrenous or tuberculous mastitis is present, death is unlikely; but it is

* This new article on mastitis in cattle replaces the former article in this series published in this Journal, Vol. 9, p. 56, 1943.

only too common for one or more of the affected quarters to go blind.

Diagnosis.—In acute and even sub-acute cases diagnosis presents little difficulty; but in the others it is frequently impossible to decide from a clinical examination whether or not a quarter is affected. Various attempts have been made to devise rapid means of diagnosis. One of these, just mentioned, is the strip cup, whereby a few jets of milk are directed on to a specially made black surface on which the clots are easily recognised. In another, a jet of milk is used to wet a piece of paper impregnated with a dye such as brom-cresol-purple; abnormal milk will change the colour, yellow to purple. Another test, which is gaining popularity, is the so-called Resazurin test, which may be combined with rennet. The Resazurin test depends on the fact that an abnormal increase in the cell content of milk will give rise to a very rapid reduction of this dye, changing the colour from the original blue, through lilac, mauve, pink, and even to white. In the rennet test abnormal milk from damaged quarters tends to produce poor clotting or delayed clotting. These two tests can be used in conjunction on the one sample at the one time. Special tablets are available for the farmer to do a test of this nature on his own; but the interpretation has to be watched carefully and instruction should be sought from a dairy officer before a farmer embarks upon routine testing of this nature.

The only certain method, however, of making a diagnosis is by the bacteriological examination of a sample of milk. Where the farm is situated close to the laboratory this is a relatively simple matter. As every dairyman knows, however, it is far from easy to obtain a clean sample of milk; and, if examination is delayed, milk being an excellent culture medium, the presence of pathogenic bacteria may be concealed by the rapid multiplication of milk-souring and other extraneous organisms.

Before collecting a sample, a small bottle and cork should be sterilized by boiling. The teat of the suspected quarter should then be washed with clean water containing disinfectant, and excess moisture should be removed with a clean cloth that has been soaked in disinfectant solution and then wrung out. Two or three pulls should be given to the teat to flush out the canal and then the bottle should be filled direct from the jet. Care should be taken that the cork is not contaminated whilst the bottle is being filled. The bottle should be dispatched

at once to the laboratory with a letter giving details of the case.

The cultivation and identification of organisms from milk occupy several days, and a report, therefore, cannot be sent off immediately the specimen is received.

Treatment.—There have been great advances recently in efficient treatment of this condition, using the modern antibiotics such as penicillin, streptomycin, aureomycin, and so on. Recent survey work done in the United States of America proves conclusively, however, that treatment to be successful must be combined with prevention in the herd. Penicillin is probably the most useful weapon to use; but one must be careful not to abuse it but always to apply full and efficient dosage, since otherwise these is the risk of setting up within the herd penicillin-resistant strains of the organism. Probably the procaine salt in an oily vehicle is the most efficient form of the drug. It is recommended that not less than 25,000 units per 24 hours be given for three applications. The most satisfactory method of application is naturally the single dose, tooth-paste-like pack, one to each teat. In the case of proved sub-clinical infection, usually *Streptococcus agalactiae* at the time of drying-off the cow, infected quarters should be given either two or three doses at 24 hours of not less than 20,000 units, or two or three applications of 100,000 units at 72-hour intervals using penicillin in cerate. It should be noted also that general treatment by way of intramuscular injection is not likely to succeed, since this results in insufficient local concentration within the udder tissue to produce the necessary effect. Penicillin alone is not too efficient against staphylococcus organisms; for these there should be combined therapy, e.g. penicillin plus streptomycin, with or without additional sulpha drugs, e.g. sulphathiazole or sulphafurazole. These have been proved to be non-irritant to healthy tissues and highly efficient against staphylococci, coliform organisms, pseudomonas, etc. One should not lose sight of the necessity for removing the tissue debris which accumulates within the milk cistern and the milk spaces of the udder. Recent American thought tends towards stimulating such removal by the intravenous injection of things such as oxytocin, but this is a matter which should be subject to proper veterinary supervision. An alternative is the local removal of such material by frequent stripping, with or without aseptic infusion of the udder with warm solution of the dyes, such

as flavin preparations, entozon or acriflavin are examples.

With regard to prevention it should be realised that the milking machine can be one of the prime factors in spreading sub-clinical infection in a herd, if proper precautions are not observed. This goes also of course for the hands of the milker, udder cloths, etc. Teat hygiene, with the prevention of injury and the control of excess dust or mud, are other factors to which the careful farmer will give his greatest attention. He should be careful not to import any infected cattle. Veterinary advice is advantageous in all these points. Infected cattle should if possible be milked last and kept separately from the rest of the herd. This is of less importance where the cattle do not spend hours or days in byres, as happens overseas.

Public Health.—Much research work has devoted to the study of the public-health aspect of mastitis. The controlling factor is

that the public is entitled to be supplied with believed normal milk only; and it is in the interests of the producer not to supply otherwise. Milk that is obviously abnormal in appearance, or known to be from infected quarters, should of course not be mixed with bulk supplies for human consumption.

In the case of apparently normal milk from infected quarters, in the vast majority of cases it has been shown that the bacteria present, usually streptococci, are not types likely to cause sore throat or other human diseases. It is, however, obviously undesirable to sell such milk, and it is, therefore, recommended that it be pasteurized and fed to calves.

It should be hardly necessary to say that mastitis milk of any kind should be regarded as infective material and should be sterilized as quickly as possible by pasteurization or by boiling, whether it is to be discarded, fed to pigs or fed to calves.

THE WATER HYACINTH

Now a "Prohibited Immigrant"

The attractive amphibious floating plant, *Eichhornia crassipes* (Mart.) Solms, generally known as the "Water Hyacinth", is considered to be a grave menace to the water resources of Kenya and the whole Nile system. Its rapid vegetative reproduction and easy dispersal in water and the property of being able to persist as a land plant during the dry weather, makes it, when once established, virtually impossible to eradicate and control involves great cost and continued effort. The plant is a native of tropical South America but has been introduced into a number of countries, originally as a horticultural speciality for water gardens and as an aquarium plant by aquarists. Its rapid multiplication soon turns it into embarrassment with the result that surplus plants have been thoughtlessly discarded and have been the cause of serious infestations of rivers ponds, dams and lakes.

In countries where the plant has been allowed to establish itself, it has quickly got out of control and has caused obstruction of navigable waterways, blocking of irrigation channels, the ruin of fisheries and the choking of expanses of still water.

Although limited in the tropics to an altitude zone of from sea level to about 4,500 ft., the plant could invade and seriously affect much of Kenya's inland waters. It has already established itself in parts of the Belgian Congo and Tanganyika and has been offered for sale in Kenya. The Kenya Government has now scheduled this dangerous plant as a "noxious weed" under the Suppression of Noxious Weeds Ordinance (*Official Gazette*, Legal Notice No. 534, dated 22nd November, 1956). Similar action has already been taken by the Uganda and Belgian Congo Governments. This legislation enables the Government to order the destruction of this dangerous weed wherever it may be found to occur in the Colony and to prohibit the offer of this plant for sale in Kenya.

LEGUME INOCULATION—A METHOD OF TESTING RHIZOBIUM CULTURES

By R. A. Robinson, Scott Agricultural Laboratories, Nairobi

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A major feature of work on the nitrogen-fixing bacteria of legumes (*Rhizobium radicola* Hilt. & Störm) is the method by which the various strains of bacteria are tested with appropriate legumes for nodule formation and effectiveness in nitrogen fixation.

Previous workers [1] [3] have stressed the necessity of carrying out such tests under conditions that are proof against contamination; and this is confirmed by experience in these laboratories. It was found that when nodulation/nitrogen-fixation tests were carried out in open pots or jars, the uninoculated control plants generally formed nodules as soon, or nearly as soon, as the inoculated plants. This phenomenon is perhaps more marked in institutions where there is a considerable amount of work with *Rhizobium* in progress.

Thornton [2] describes a contaminant-proof method of growing the test legumes on agar in a totally enclosed, cotton-wool-plugged boiling tube. Wilson [3] describes a similar totally enclosed method involving the use of nutrient-impregnated sand in place of agar. He expresses doubts about the reliability of methods that employ "semi-sterile" conditions, in which the legume roots are protected from contamination while the shoots are allowed to grow exposed in the open.

In addition to complete proofing against contamination, a test method should possess various other features. When large numbers of tests are required, each of them replicated, it is essential that the apparatus can be quickly assembled, and easily and effectively sterilized in quantity. Except for large legumes the use of bulky containers is consequently inadvisable, as these generally have to be autoclaved individually.

When a test plant is grown under conditions that are proof against bacterial contamination, its environment is inevitably somewhat artificial. However, the growing conditions must be sufficiently near to normal to allow easily measurable growth and colour differences between the nitrogen-deficient controls and the nitrogen-fixing test plants.

As most test legumes require between six and ten weeks of growth to show such growth and colour differences, provision must exist for replenishing moisture in the rooting medium without opening the apparatus and so risking contamination. Some allowance must also be made for the increase in concentration of the nutrient solution following evaporation.

Finally, all growing conditions such as the rooting medium and its degree of drainage, the composition and rate of evaporation of the nutrient solution, light intensity, day-length, temperature, etc., should be standardized as far as is possible.

A previously described [4] method was used in these laboratories for some years. This method involved the use of boiling tubes as containers since these could be easily prepared and autoclaved in quantity. Sand moistened with a suitable nitrogen-free nutrient solution was used as a rooting medium in preference to agar, because it was less susceptible to the fungal weed growth that may occasionally occur. However, it was found that these tubes were apt to become water-logged both at the time of preparation and with each subsequent watering. They were also liable to dry out completely if not carefully watched. In addition, removal of the cotton-wool plug for watering led to an increased risk of contamination, which, if the test was prolonged, began to defeat the object of total enclosure of the test legume.

These difficulties have been overcome in a new method which is now in regular use. The method is based on unusually large Roux culture tubes which were specially manufactured*, 12 in. in height, 1½ in. in diameter and with the constriction 2 in. from the bottom (Fig. 1). To prepare a tube for a test, a small strip of absorbent cotton-wool is wrapped around the end of the "ventilation tube". This is a six-inch length of glass tubing, which permits a free passage of air between the two compartments of the Roux tube. The ventilation tube must have an internal diameter of not less than 6 mm., because narrower tubing

* By Messrs. A. Gallenkamp & Co. Ltd., London.

is liable to develop air locks when wet. The ventilation tube is placed in the Roux tube so that the cotton wool both plugs the constriction and holds the ventilation tube in position. Approximately 100 gms. of dry sand are then poured into the Roux tube, followed by approximately 50 ml. of a suitable nitrogen-free nutrient solution. It is sufficient to measure both sand and solution with a standard measure such as a 50 ml. beaker and a funnel greatly facilitates the pouring. The excess of nutrient solution drains through the sand and all but fills the reservoir below the constriction, where it remains as a reserve. Should the ventilation tube project below the constriction, it should now be pulled upwards with a pair of long forceps until the end of it is in contact with, but not obstructed by, the absorbent cotton-wool plug. The Roux tube is plugged with non-absorbent cotton-wool and autoclaved. It is then ready for use.

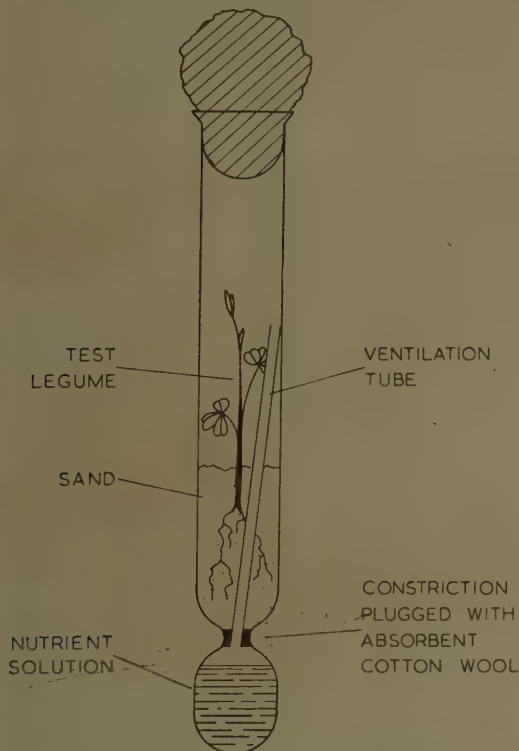


Fig. 1.—Diagram of the modified Roux tube

Following standard practice, the seeds of the test legume should be surface sterilized by immersion in a 0.1 per cent solution of mercuric chloride, or in concentrated sulphuric acid, followed by three or four washes in

sterile water. To avoid sowing dead seed, pregermination under sterile conditions is advisable; and when sowing pregerminated seeds it is as well to bury them with a suitable sterilized wire or needle to ensure uniform development of the test plants. Inoculation can be carried out either by adding a drop of bacterial suspension to each Roux tube or by bulk inoculation of the pregerminated seeds after the control tubes have been sown. Since a nodulation/nitrogen-fixation test is only of value if the culture used is absolutely pure, it is a sound practice to do a routine purity test on each culture before inoculating the seed. In this connexion, it has been found that the use of water mounts of living bacteria examined through a phase-contrast microscope is superior to conventional smear methods.

The tubes are conveniently held in wooden racks, each rack holding the four inoculated and two control tubes, which are adequate for one test. For the duration of the test, the rack is placed under a battery of six 5-foot, 80-watt fluorescent lamps producing a diffuse light of about 200 Weston units. The lamps are cooled by a small electric fan and, in these laboratories, this provides sufficient control to keep the day temperature constant at 20-24° C. A standard day-length of 12 hours is obtained with a time switch. The batteries are easily accommodated on a laboratory bench, and each battery will hold 24 racks of six tubes each. When under these batteries, the tubes lose between one and two grams of water by evaporation each week. Consequently a nutrient solution 10 per cent below strength is used when preparing the tubes, and this solution is then approximately 10 per cent over strength when the test is completed.

In numerous tests now completed with this method, it has been found that the conditions of a satisfactory test method are largely fulfilled. The test legume is totally enclosed and no contamination has been recorded. The apparatus is easily and quickly set up and autoclaved in quantity. Waterlogging of the tubes is impossible and drying out of the tubes beyond the critical wilting point does not occur. Moisture replenishment of the rooting medium is achieved, without risk of contamination, by laying the tube or rack of tubes in a horizontal position for a few seconds; and it is thus necessary to open each tube only once during the entire duration of the test. Finally, the method produces very definite results. With various species of small-seeded

legumes, such as *Trifolium*, *Medicago*, etc., the inoculated plants grow to a height of six inches and are a dark green colour; while the uninoculated control plants, in a nitrogen-free medium, grow only until the nitrogen reserves of the seed are exhausted (Fig. 2). These control plants are generally about two inches high and exhibit symptoms of extreme nitrogen deficiency. (It is worth noting that the very marked increase in size of the inoculated plants is produced by generally only one, sometimes two, quite small, pink nodules.) Conversely, if the strain of *Rhizobium* does not fix any nitrogen with the test legume, all the inoculaed plants soon show symptoms of poor growth and nitrogen deficiency identical with those of the controls. Examination of the roots will then show whether ineffective nodules or no nodules at all have formed.

With larger-seeded legumes, possessing a greater reserve of seed nitrogen, the growth and colour differences are less marked. The method is not so suitable for very large-seeded legumes, such as peas, beans, etc., since their seedlings tend to outgrow the tubes before nodules have time to form.

The kind assistance and continued interest of Dr. R. M. Nattrass throughout the progress of this work is gratefully acknowledged.

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Fig. 2.—*Trifolium Pratense* Test Result. This test has been continued for twelve weeks. The backs of the upper portions of the tubes have been painted white for photographic purposes

CATTLE TWINS AND THEIR USE IN RESEARCH

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Many readers of this journal will have noticed in the agricultural Press recent appeals for identical cattle twins, required for research into animal production problems. The appeals have been published jointly by the Kenya Departments of Agriculture and Veterinary Services and the Joint Animal Industry Division of E.A.V.R.O. and E.A.A.F.R.O. They have of necessity been short; and the object of this article is to give a clearer picture of the type we actually require and say a little of how their use assists us in our work.

In Kenya the frequency of twinning is not yet known, but in European Countries about 1 per cent of cattle births result in twins. Most are fraternal twins and have arisen because at one oestrus the cow shed two ova, which were fertilized by separate sperms. Occasionally however a pair of twins are found that have resulted from the splitting of a single fertilized ovum to form two embryos, and it is these twins that are called monozygous or identical.

It is the fact that identical twins have developed from a single cell and are therefore genetically alike that makes them of particular value for research. The reason is because in experiments where they are used it is then possible to have both control and experimental animals that are genetic replicates of one another. The importance of this becomes clear when it is realized that milk production, rate of growth or any other trait one measures is influenced both by genetic as well as environmental causes. For instance, if we were experimenting with two grazing systems, we would probably find that some animals on the poorer treatment would do better than several of the animals on better grazing because they were genetically superior. This is illustrated in an experiment of Hancock's conducted in New Zealand, where on two systems of management (B and C) the butterfat yields in 1948 were as shown in Table I.

It will be noticed that three cows on treatment C were better than the worst receiving ration B. If these animals had all been unrelated, it could be shown by an analysis of variance that the differences between treatments, although important economically, would have been too small to be statistically

significant (5 per cent level) unless many more animals had been included in each group. The animals in each row were however twins, and looking again at Table I it will be seen that in each pair the cow on treatment B always had the higher yield. Statistically, differences between pairs can be eliminated and the differences between treatments are then found to be significant.

TABLE I—BUTTERFAT YIELDS IN 1948
Treatments

B		C		Dif.
Cow	Yield (lb.)	Cow	Yield (lb.)	
24 ..	429	22 ..	397	32
36 ..	288	35 ..	279	9
37 ..	495	38 ..	428	67
59 ..	303	60 ..	269	34
94 ..	424	93 ..	393	31
Average ..	388		353	35

The main advantage of using twins is therefore to increase the accuracy of experimental work and to reduce the number of animals needed on each experimental treatment.

The number of unrelated animals a pair of twins can replace depends on the importance of heredity in controlling the character being studied. Twins are of greatest value if heritabilities are high, declining as heritabilities decrease, until, under conditions where environmental differences cause all the variation, they have no more value than unrelated stock. If however the criterion studied is connected with growth or milk production, then in experiments like Hancock's one pair of twins can usually be relied upon to replace between six to ten pairs of unrelated cows. This does not mean that experiments can be conducted using only single sets of twins, because then the results could not be generally applied. Normally at least five sets are used depending upon the importance of the trial; but even then considerable saving is made in animals and space, and also in staff needed for recording the results.

In all countries where twins are used, the methods employed for diagnosis of monozygous twins are based on careful visual examination to eliminate the fraternal pairs. This method leaves as identical the sets that are so similar that the only explanation of their similarity can be that they were derived from a single egg and are genetically alike.

Sex is an obvious genetic difference and we can immediately eliminate as fraternal all pairs where one twin is a heifer and the other twin a bull. Sets of differently coloured calves, or pairs that are particularly easy to tell apart because of differences in conformation, can also be discarded and not considered further.

We are now left with twins that are—

- (1) the same sex;
- (2) the same colour;
- (3) difficult to tell apart.

These are the twins our collector wants to see. On being notified that a farm has twins that meet these three requirements, we arrange to see them whilst on our next *safari*. The twins will then be thoroughly examined to find all the differences there are. It should be stressed that no two calves are ever in all respects identical and the term identical is apt to be misleading.

The collector looks first for minor differences in colour. On any calf the colour varies in shade on different regions of the body and each area is separately compared. Whilst calves are small, differences between the legs or on the neck are easiest to see. Colour is considered an important diagnostic feature and no differences in shade can be allowed. Even slight differences in shade indicate that two eggs were involved and the twins are not identical.

Similar strict standards are used for judging conformation. Frequently differences in head shapes or the structure of the rump lead to their rejection; but providing the set survives so far the next point to be considered is whether or not there is similarity in the pattern on broken-coloured animals. Unfortunately pattern is not completely genetically controlled, and even on the same animal considerable differences are often found between the pattern on the left side and on the right. Figs. 1, 2 and 3 were taken of a typical pair of monozygous Ayrshire twins. As a general rule the pattern on both twins must be as similar as would be the two sides of a single calf. One can then imagine what the differences would be if a single calf were divided

into two, which is what happens in forming monozygous twins.

The general pattern must always be the same, especially on extremities. Besides being generally alike the heads in Fig. 2 both have the same brown spot encroaching from the muzzle and also the white mark that tends to circumscribe the nose. It will be seen from Fig. 3 that the legs are also practically the same. The feet are brown, and on both calves the brown pattern extends from the feet up the posterior surface of the legs to just below the knees. The brown flecks in the white patches on the legs are an unusual feature, which supports the diagnosis that these twins are actually identical.

Fig. 1 shows the markings on the remainder of the body. They are not identical but the amount of white is approximately the same and the coloured patches are similar in size. The patches themselves have the same irregular outlines and the patterns on these twins are in fact as similar as the two sides on any one of them. Both calves have a white patch extending upwards from the throat and it will be noticed that the patches form lines that cross the calves at about 45 degrees. For the purpose of diagnosis these patterns are therefore sufficiently alike; and this point should be stressed as many people fail to notify twins that have patterns similar to these, because they think they are not sufficiently alike.

Although on monozygous twins the patterns need not be quite alike, many pairs are still rejected through differences in pattern. Sometimes one has more white or more roaning than the other or a white blaze or mark which the other lacks. Often the patches have different types of outline; one may be broken while the other is definitely smooth. These differences are certainly genetic and lead to a dizygous diagnosis.

Monozygous calves have similarly textured coats. One coat must not be rough if the other is smooth. Changes of direction in hair cause whorls and these must correspond. The whorls on the face are seen in Fig. 2 and are of great assistance to accurate diagnosis. On the face the whorls differ in type and in position; but on the pair illustrated they are obviously the same. Others are found above the eyes, upon the poll and always on the back. On the pair being demonstrated the back whorls are shown in Fig. 1. On both calves these form a group of vertical white hairs. In Fig. 1 one can also see the similar upward curl over the tails of these two animals.



Fig. 1.—A pair of monozygous twins showing differences in pattern on the bodies, which are not sufficient to change the diagnosis

[Photo by A. J. Searle]

Fig. 2.—The heads of the twins shown in Fig 1. Note the hair whorls and similarity of the markings round the muzzle

[Photo by A. J. Searle]



Fig. 3.—The front legs of the same pair of twins. They both have brown feet and similar patches on their legs. The brown flecks visible in the white areas are an unusual feature which supports the diagnosis

[Photo by A. J. Searle]

Lastly the collector will examine the colour of the mouth and compare the similarity of the fingerprint-like patterns found upon the nose. The number and size of teats will also be examined, together with any peculiarities on either of the calves.

The final diagnosis depends on considering all the differences found and deciding if they indicate the difference is genetic. In practice the task is not unduly difficult and even dizygous twins that are superficially alike will be found to differ in as many as three or four important points, compared with only insignificant differences between monozygous pairs. It is found that provided the collectors correctly look for differences and not for similarities when drawing their conclusions, few cases occur where trained observers are unable to agree.

Although subjective, the method described is at present the only satisfactory means of diagnosing twins. Methods based on blood groups or epithelial antigens are not so satisfactory because of complications due to pre-natal vascular anastomosis, which occurs between both dizygous and monozygous twins. This makes most dizygous pairs genetical mosaics, and is the same phenomenon that makes "free-martins" out of the majority of heifers that are born twins to bulls.

In Europe the proportion of twins of like sex that are found to be identical is approximately one in every eight or nine, and appears closely related to the theoretical frequency of monozygous twins as calculated from the excess of unisexual over heterosexual births. Although it is not known how many we will find, early results in Kenya indicate that the proportion is not lower than it is in England, and may well be slightly better. In fact we have found seven monozygous pairs in 25 examined. Seven pairs are however not enough to meet our needs, and, as twins are urgently required, we would like to repeat our appeal to farmers who own twins which they would sell and think may be identical, to inform G. H. Lampkin, P.O. Box 21, Kikuyu, or their local Agricultural or Veterinary Officer who will pass on the information.

All notifications will be promptly acknowledged and arrangements made to come and see the twins. It is regretted that visits may not be possible immediately because it is necessary to arrange our journeys economically. Farmers are therefore requested *not* to notify twins they would not normally be rearing, because it will not be possible to compensate for foodstuffs consumed by twins that are not purchased as identical.

A NOTE FOR CONTRIBUTORS TO THIS JOURNAL

Please prepare articles for publication in this Journal in accordance with the following system:—

- (1) Type in double spacing, with a wide margin; and send an *original* typing, not a carbon.
- (2) Revise the manuscript very carefully to eliminate errors of spelling, mis-typings, etc., and ensure that punctuation is correct. Pay special attention to the use of capitals.
- (3) Start the article with a brief "SUMMARY".
- (4) Divide the article suitably into a few main sections and include headings for the sections.
- (5) Have tables typed on separate sheets—not in the body of the text—but show in the text where each table should be inserted.
- (6) When you quote another author, include his name and the date of his article in the text; e.g. "(Vinson and Petre, 1929)". Then in the "REFERENCES" at the end, list the authors alphabetically and quote their papers in the following form: name, date, title of article, publication, volume number, pages; e.g. "Vinson, C. G., and Petre, A. W. (1929). Mosaic Disease of Tobacco. *Bot. Gaz.*, 87, 14-38."
- (7) Draw text figures, graphs, etc., in Indian ink on Britol board or faintly squared paper. *Do not ink in numbers or lettering*; enter these in pencil and the Printer will do the rest.
- (8) Please try to send photographs with the articles: good glossy prints, as large as possible, with captions typed on a separate slip and pasted on the back. *But write very lightly*. And supply captions also typed on a separate sheet.

A NOTE ON A WILT OF GROUNDNUTS DUE TO *SCLEROTIUM ROLFSII* SACC., IN TANGANYIKA

By P. K. S. Clinton, formerly Plant Pathologist, Overseas Food Corporation, Southern Province, Tanganyika

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The work described in this paper was carried out at the experiment stations of the Overseas Food Corporation in Tanganyika, at Urambo, Western Province, and at Namanga, Southern Province, in 1950 and 1951, respectively.

FIELD OBSERVATIONS

In February, 1950, following a wet period, a wilt, accompanied by browning of the foliage, was noticed in groundnuts of the variety Natal Common in poorly drained areas, particularly on red and red-chocolate soils at Urambo. The plants bore a more or less heavy white felted mycelium on the roots, from which dark brown sclerotia were formed. The fungus was identified as *Sclerotium rolfsii* Sacc.

The initial incidence was below 1 per cent, but in the continuously rainy part of February, the disease spread rapidly along the rows, up to six plants being infected from each focus of infection. The roguing of infected plants and the occurrence of a dry period in March checked the further spread of the disease.

Towards the end of the season, in April, premature wilting and death of the haulms occurred in sections of rows five or six yards long, in which the plants were, on average, five to six inches apart. A continuous weft of mycelium was found joining the root systems along the row. At this time harvesting began, and the fungus spread rapidly on the plants which lay in the field after digging, before they were stooked.

Although little direct damage was apparent in the crop, the attachment of the pods to the haulms was weakened, so that many were shaken off and lost in the course of mechanical lifting, and in the subsequent picking up and stooking by hand. Up to 50 per cent of shed pods gleaned were infected with a white rosy mycelium resembling that of *Sclerotium*, but *Sclerotium rolfsii* could only be isolated from 2 per cent. Fewer than 1 per cent of successfully harvested nuts were infected.

Damage by *Sclerotium*, like any other form of damage to short-season groundnut pods, may lead to germination of mature nuts in the

soil before harvesting, or in the stooks afterwards.

In December, 1950, *Sclerotium rolfsii* was seen in volunteer (self-set) groundnuts at Namanga, Southern Province. The self-set population was 13,000/acre, and in one area of about 1/4 acre, 80 per cent of the plants were affected. The field was disc-ploughed (Massey-Harris 504) to six to eight inches depth, and planted with groundnuts. The new crop was free of *Sclerotium* infections, but two self-set plants which came from nuts buried up to ten inches by the ploughing were found to be infected.

The wilt was seen in many parts of the Southern Province area in 1951, which was the first year of large-scale groundnut production by the Corporation in that area. It was most pronounced in places liable to water-logging. Excessively high ridging-up (up to 8-10 in.) of maturing plants accelerated the spread of the disease along the rows. In these cases buried parts of the stem and petioles were affected.

In some of these cases *Sclerotium* was associated with a bacterium which was not identified.

LABORATORY INVESTIGATIONS

The life cycle of the fungus was studied in culture. *Sclerotium rolfsii* Sacc., of the order Fungi Imperfecti, sub-order Mycelia Sterilia, is typically in culture a white floccose mycelium of hyaline septate hyphae, producing sclerotia 1-2.5 mm. in diameter, which become hard and black or dark brown when mature.

Of three standard media used, Malt, Cornmeal and Potato Dextrose (as supplied in dehydrated form by Difco Laboratories) the last named gave the best growth. Growth on the other two was thin and adpressed, with poor and slow production of sclerotia.

Subsequently two media based upon groundnuts were used. A decoction of groundnut kernels was made by boiling a kilogramme of kernels with about half a litre of water in a pressure cooker at 15-lb. pressure for two

hours. The resulting liquid was strained off and used with the addition of 2 per cent powdered agar. This medium gave a slow and atypical half-submerged growth of an attenuated mycelium, and very small (0.5-1.0 mm.) but viable sclerotia.

Finely ground groundnut shells were used in a plain agar base, about 5 per cent of the powdered sterilized shell being added after the agar was made up. This medium gave extremely vigorous growth of normal type. Large viable sclerotia (1.5-3.0 mm.) were produced in profusion, particularly at the plate edges where the hyphae were forced upwards.

Effect of formalin.—Difficulty was found at first in obtaining cultures free from bacterial contamination. Surface sterilization with formalin was tried. Sclerotia were soaked in solutions of varying dilution for one hour, washed with sterile water, and planted on to agar plates. The controls were washed with sterile water only for the same period.

The data in Table I indicate that treatment with increasing concentration of formalin delays and finally inhibits germination of sclerotia, with an apparent 50 per cent lethal level of formalin between 1 per cent and 2 per cent. Some sclerotia were able to make feeble growth even after treatment with 2 per cent formalin.

TABLE I.—EFFECT OF TREATMENT WITH VARIOUS CONCENTRATIONS OF FORMALIN ON GERMINATION OF SCLEROTIA

Treatment	No. in Trial	No. GERMINATED AFTER		
		36 hrs.	48 hrs.	72 hrs.
Control ..	61	58	59	59
Formalin 0.5 per cent ..	20	10	18	18
Formalin 1.0 per cent ..	20	0	10	14
Formalin 2.0 per cent ..	20	0	0	2

It is unusual for sclerotia of *S. rolfii* to be so sensitive to very short exposures to formalin. Leach and Davey [8] found that concentrations of formalin down to 0.02 per cent were effective in killing sclerotia, but only over very much longer periods of exposure, from 6 to 24 hours. Ciccarone and Platone [9], in Venezuela, found that 12 hours exposure to

gaseous formalin from a 1.5 per cent solution killed 77 per cent of the sclerotia.

Thorough washing with sterile water was found to be sufficient to prevent contamination in the controls above, and was satisfactory on subsequent cultures.

Effect of acidity of medium.—In all the following trials potato-dextrose agar was used. Although the growth was less vigorous than on groundnut-shell agar medium, it was quite adequate, and the medium was more easily made up to standard conditions.

Sclerotia were plated out on to media adjusted to various pH values by the addition of McIlvaine buffer solutions, and the subsequent germination and growth recorded (Table II). The initial and final pH of the media were determined by the use of B.D.H. Universal Indicator, which did not give values below pH 3.5. Ten sclerotia on two plates were used for each treatment.

In cultures of initial pH 3.5 and 4.3 growth was much interrupted by the formation of excess acid, which caused liquefaction of the media. The extent of liquefaction seemed to indicate a final pH of about 2.

Germination was unaffected by initial pH between 3.5 and 6.1, but initial growth was better on the more acid media (pH 3.5-4.8). Higgins [1] noted that no growth or germination took place at pH 1.4 in certain other strains of *S. rolfii* and pointed out that oxalic acid produced by the fungus on dextrose media, amongst others, was lethal at 2 per cent and would severely inhibit growth at 1 per cent.

Growth on media of initial pH 6.1 was thin. Except on those media which liquefied, viable sclerotia were produced in all treatments.

TABLE II.—EFFECT OF pH OF MEDIUM ON GERMINATION AND GROWTH OF SCLEROTIA OF *S. rolfii*

Initial pH	Number germinated after 24 hrs.	AVERAGE DIAMETER OF COLONIES		Final pH (5 days)
		after 48 hrs.	after 72 hrs.	
3.5	10	13.8mm.	very irregular	3.5
4.3	10	13.3mm.	irregular, 5-30 mm.	3.5
4.8	10	13.7mm.	Regular and overlapping	3.5
5.2	10	11.6mm.	"	3.5
5.5	10	8.1mm.	"	3.5
6.1	10	6.6mm.	"	3.5

The pH of soils in the Southern Province was on average slightly lower than that in Western Province soils, those of Namanga ranging from pH 5.1-6.5. About four-fifths of the Urambo red soils were neutral or actually alkaline, their pH being from 6.5-8.0 [2]. In these soils, however, the pH was usually much lower, to about 5.2, at 6 to 12 inches depth. Nevertheless, the marked preference for acid conditions suggested in Table II appeared to have little effect upon distribution in the field. There seems to be no doubt that the fungus is capable of rapidly reducing the pH of its immediate environment, and at depths where infection normally occurs, the soil conditions are not fully known. Higgins [1] records that the heavy liming of certain American soils, bringing their pH to above seven, did not effect any control of the fungus; and other writers [4] have shown that strains of *S. rolfsii* can tolerate pH values of up to 8.0. On different media this can be increased to nine, but sclerotial production was found to be reduced above pH 6.

Effect of temperature.—Sclerotia were exposed to dry heat for varying periods to find their thermal death points under these conditions. Twenty sclerotia were used for each treatment and were afterwards plated out, ten to a plate, on potato-dextrose agar.

TABLE III.—EFFECT ON GERMINATION OF SCLEROTIA OF EXPOSURE TO VARIOUS TEMPERATURES FOR VARIOUS PERIODS OF TIME

Temperature °C.	Time	No. Tested	SCLEROTIA GERMINATED	
			after 24 hrs.	after 48 hrs.
50	1 minute	20	20	20
50	5 minutes	20	20	20
50	10 minutes	20	20	20
55	1 minute	20	20	20
55	5 minutes	20	20	20
55	10 minutes	20	20	20
60	1 minute	20	20	20
60	5 minutes	20	20	20
60	10 minutes	20	0	10
65	1 minute	20	0	4

From the figures in Table III, it may be seen that exposures for up to ten minutes to temperatures up to 55 degrees had no adverse effect upon germination. Ten minutes at 60° C. or one minute at 65° C. heavily reduced germination.

The optimal temperature range for mycelial growth was studied using potato-dextrose agar plates with ten sclerotia in each treatment.

The plates were kept in incubation chambers maintained at four different temperatures for 48 hours immediately after being sown with sclerotia. Results are given in Table IV.

TABLE IV.—EFFECT OF AMBIENT TEMPERATURE ON RATE OF GROWTH OF MYCELIUM OF *S. rolfsii*

Temperature °C.	Average Colony diameter after 48 hours	Number germinated
25	10.5 mm.	10
29	25.0 mm.	10
37	11.75 mm.	7
37	11.8 mm.	10
39	no growth	(10)
39	no growth	(10)
43	no growth	0
43	no growth	0

At 37° C. growth was markedly less than at 29° C.; and at and above 39° C., growth was inhibited entirely. When removed from the chamber after 72 hours at 39° C. the sclerotia were found to be viable at normal temperatures. At 43° C. germination was prevented, and on removal to normal temperatures, the sclerotia were found to have been killed.

Similar figures were obtained using cultures on groundnuts kernel and groundnut-shell agar plates, at 25°, 28° and 32° C. Peak growth occurred on both media at 28° C.

These figures correspond remarkably well with those of other workers. Thus Higgins [1], using strains of *S. rolfsii* isolated from pepper, potato, etc., found that mycelial growth could not take place at 40° C., 37° C. being the maximum at which normal growth occurred. The optimum temperature was 32° C.

Fajardo and Mendoza [3], with strains isolated from groundnuts in the Philippines, found an optimum temperature of 28°-30° C., and 42° C. was the highest temperature at which sclerotia germinated. Exposure to dry heat for one minute at temperatures of 60°-62° C. they found to kill the sclerotia.

At Urambo temperatures up to 51° C. were recorded immediately below the soil surface in the dry season. Sclerotium infections however normally take place fairly deep in the soil, down to about eight inches. The temperatures appear to be high enough to prevent any mycelial survival over the dry season except at considerable depth; but the sclerotia

are not likely to be severely affected, even by the immediate sub-surface temperatures.

Effect of desiccation.—The effect on sclerotia of prolonged exposure to dry conditions was tested by putting sets of ten sclerotia on dry filter paper in Petri dishes and enclosing them in a small chamber with a large silica-gel drier. Germination on potato-dextrose agar after four days was 100 per cent. Of ten sclerotia plated out after five weeks' drying, only two germinated; and after ten weeks' drying none of the remaining ten was viable. Such a low resistance to desiccation appears to be unusual in the species. In the Philippines, Fajardo and Mendoza [3] reported that sclerotia from groundnut-attacking strains survived 12 months' dry storage.

Mycelium kept in airtight tubes did not produce sclerotia, but after eight months was found to be quite able to continue typical growth and development when plated out under normal conditions, and sclerotia were then produced.

In natural conditions in Tanganyika, the long dry season, from May to December, dries out the soil to a considerable depth. This may be a major factor in reducing potential infection by *S. rolfsii*. Although it is able to spread at great speed along rows of close-spaced groundnut plants, the severity of infection never approaches that recorded in reports from South Africa [5] [6] or the United States and South America [7] [9].

Effect of light.—Cultures of *S. rolfsii* on potato-dextrose agar kept in the dark showed a thinner, more attenuate mycelium than cultures from the same mycelial source kept in the light. Sclerotial initials were formed, but the hard dark mature form of the sclerotia did not develop. Plates that had been kept continuously in the dark for a month without developing sclerotia produced abundant normal-looking and viable sclerotia after two days in the light. This effect, to which the writer could find no previous reference, has recently been confirmed by observations of other workers in America [10].

Experimental infection of groundnuts.—Twenty groundnuts of the variety Natal Common were planted at a depth of one inch in pots of soil, and one sclerotium was placed in contact with each. In 16 days 19 of the resulting seedlings showed typical infections.

Samples of soil from an infected area, and from one where the disease had not been observed, were taken and used to grow ground-

nuts in tins. Three plants out of 60 in the former, and none in the latter soil, became naturally infected.

Seedlings at 3-, 6- and 9-days old were removed from the soil-and-sand mixture in which they were growing, and eight of each were laid on sterile sand in dishes. One sclerotium was placed in contact with each hypocotyl. All the sclerotia germinated, and in the 3-day old seedlings six out of eight showed yellow lesions on the hypocotyl after 24 hours. Growth of the fungus was vigorous and sclerotia were produced after two days. In the six-day old seedlings, five out of eight showed typical infections in 48 hours. Sclerotia were not produced until after six days. Six of the nine-day old plants became infected, and growth of the fungus was apparently normal, but no sclerotia had been formed in six days. There appears to be no development of resistance to infection in older seedlings, although formation of sclerotia is delayed.

DISCUSSION

The ability of *Sclerotium rolfsii* to attack groundnut plants from the earliest stages of their growth and its ability to spread with great rapidity from one plant to another, particularly in plantings as close as was found desirable in the mechanised production of groundnuts by the Overseas Food Corporation, would seem to imply that, once its presence in the soil had been established, it would increase year by year with continuous cropping.

There appears to be nothing in the texture or pH of the soils where it was found that would reduce the effectiveness of the fungus. The high soil temperatures, coupled with drying to a considerable depth in the dry season, almost certainly inhibit mycelial growth during these months; but, since initial growth is rapid, and mycelium from newly germinated sclerotia is immediately infective, it is surprising that a quick build-up did not occur in the soil as soon as the temperatures dropped and the rains began, towards the end of November. There was in the soil a good deal of woody debris from the recent bush clearing to provide for saprophytic growth of the fungus before the nuts were planted. That this does not happen seems to indicate an effect on the viability of sclerotia in the soil. This could be due to the effects of drying. The surface layers of the soil are not infective when the first nuts are planted, and infections do not occur until growth of the roots

has reached a considerable depth. It is at a depth of six to eight inches that these first infections are found. Volunteer plants from seed buried below eight inches have been found to become infected at this depth.

Infections are found up to depths of ten inches, but ploughing to eight inches afforded complete control, which perhaps indicates that very few sclerotia exist below this level. This may be due to the sharp decrease of organic matter below a depth of four inches in the soil. There may in fact be only a very narrow horizon of the profile in which the sclerotia are not adversely affected by one or other of these factors, so reducing the potential of infection over the dry season.

The practice of planting in the shell, which may carry with it its own infection, or of leaving large quantities of debris on the ground, would seem to be undesirable.

ACKNOWLEDGMENTS

The author is indebted to Dr. I. A. S. Gibson, Plant Pathologist at Urambo at the time, for assistance in the part of the work carried out in his area.

SUMMARY

The occurrence of *Sclerotium rolfsii* Sacc. is recorded in the western and southern provinces of Tanganyika. In the western province the fungal attack accelerated the disintegration of the plants after digging, leading to detachment of the pods from the haulms in the subsequent stages of mechanical harvesting. In the southern province the disease was much more severe, and in some cases led to the breakdown of the plant before maturity. In this area control was effected by disc ploughing to a depth of six to eight inches.

The pathogenicity of the fungus was shown by its ability to infect groundnuts of various ages when sclerotia taken from cultures isolated from infected plants were placed in contact with the hypocotyls.

The fungus produced much acid in culture, and was tolerant of a wide range of acidities.

Short periods of exposure to dry temperatures up to 60° C. did not affect viability of sclerotia, but longer exposures, or very brief ones above that temperature reduced it. Prolonged exposure to 43° C. killed the sclerotia. Mycelial growth was best at 28°-29° C., and normal growth was inhibited about 37° C. In the absence of light sclerotia did not mature.

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COMPARATIVE TRIALS OF D.D.T. AND DIELDRIN FOR THE CONTROL OF THE RIVERSIDE TSETSE *GLOSSINA PALPALIS FUSCIPES* (NEWST.)

By G. F. Burnett and J. Robinson, Colonial Pesticides Research Unit, Arusha, Tanganyika, and J. G. Le Roux, Department of Veterinary Services, Kenya

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Residual deposits of D.D.T. have been used with considerable success against the tsetse fly, *Glossina palpalis fuscipes* (Newst.), in the Nyanza Province of Kenya (Wilson, 1953). It has become standard practice to use "Arkotine", a product of Shell Chemicals Ltd. The tests here described were originally intended to give more accurate information than that hitherto available on the persistence of the formulation as used, and if possible to suggest economies.

Shortly before the work started it was decided to combine this with an evaluation of a dieldrin emulsion. When the method of treatment used in the field was observed in detail, it was realised that laboratory-scale tests could only provide comparative results, and that any recommendation on the use of dieldrin in the field would have to be based on comparison with the known performance of the D.D.T. formulation. This was because the successful field control had been obtained without carefully spraying all available resting sites, and it would be possible, immediately after spraying, to select two series of samples equivalent in other respects but of which one might be drenched with insecticide and the other be completely untouched. It was apparent that only a proportion of possible resting places need be lethal; but, since this proportion was unknown, it was decided to take a large number of random samples from bushes treated with two insecticides, to make contact tests with live tsetse flies and to compare the performance of the two chemicals on this basis.

FORMULATIONS

The Kenya Veterinary Department has standardized its technique for the residual spraying of riverine bush in the control of *G. palpalis*, as follows. Shell "Arkotine" (15 per cent w/v tech. D.D.T.) is diluted with water to give a 5 per cent D.D.T. w/v emulsion, and the emulsion is applied at a mean rate of 15 gallons per mile of bank. This D.D.T. formulation contains a small amount of coumarone resin. For comparison another Shell product

was used "Dieldrex 15", a similar miscible oil containing 15 per cent w/v of technical dieldrin, but no resin. This was used at two dilutions (a) 1.7 per cent dieldrin (being equivalent in price to Arkotine at 5 per cent D.D.T.) and (b) 5 per cent dieldrin. Both were applied at the same volume rate as the Arkotine, 15 gallons of diluted emulsion per mile of river bank.

METHODS

The selected formulations were applied in mid-November, 1955, to adjacent sections of the Angoche and Nyamaraga rivers, in South Nyanza, Kenya. Spraying was carried out by the usual methods by personnel who had been engaged in the Nyando river reclamation scheme (Wilson, 1953). One side was sprayed by one of the authors (J.G.L.) and all samples were taken from this side. The Angoche at this point has rather open vegetation, the banks at most places being exposed to sunlight. Care was therefore taken to sample only in exposed situations of the more continuous bush along the Nyamaraga. The Nyamaraga was treated with 1.7 per cent dieldrin only, the other two treatments were applied on the Angoche. The principle comparison was between 5 per cent D.D.T. and 1.7 per cent dieldrin and these treatments were made on the same day (Nov. 16th, 1955), the 5 per cent dieldrin formulation was sprayed on the following day.

Samples were taken at intervals, each consisting of ten leaves of various shrubs, ten such samples being procured from each treatment on each occasion. No attempt was made to keep to one species, but hairy leaves were avoided and highly polished ones were absent. All leaves sampled could be described as smooth but not glossy. The D.D.T. deposits on the leaves were not very obvious, whereas the dieldrin deposits showed easily visible white spots (Fig. 1). To ensure that the leaves selected were a random sample, and not biased by the psychological effect of the visible dieldrin deposit, a rigid sampling technique was

used. The points at which leaves were taken were selected by walking 30 paces and picking from the nearest bush on the right with eyes averted, leaves being picked at all heights from ground (or water) level to head height.



Fig. 1.—A photograph of leaves sprayed with "Dieldrex" emulsion diluted to contain 5 per cent dieldrin. These leaves are sprayed to a moderately heavy extent; many were more heavily sprayed and a rather higher number were less heavily treated. The larger leaf was $3\frac{1}{2}$ in. long

Biological tests were made with wild *G. palpalis fuscipes*, caught between 09.00 and 12.00 hrs. These were offered the shaven flanks of a sheep as soon as the catching party returned to camp. Flies that did not feed after the fourth opportunity, each of ten minutes duration, were considered not hungry and used for tests together with those that had gorged. Gorged and non-hungry flies were distributed evenly between each sample tested and the control; deaths varied considerably from day to day and a large proportion of the daily catch had to be reserved for the control. As a result it was not possible to test every leaf picked. However, as many leaves as possible were tested according to the number of flies available: at least six out of ten of the leaves in each sample and as many samples as the supply of test insects permitted. Test were made by gripping the fly in a pair of forceps by the two closed wings and allowing it to walk over the contaminated surface of the leaf for 15 seconds. It was then placed in a clean tube and kept in a dim light over water. Tests were made between 14.00 and 16.30 hours and mortality counted at 16.00 hours the next day.

Controls were similarly treated but were walked over a clean surface. The last series of tests, on the 5 per cent dieldrin treatment three months after application, were invalid, owing to unavoidable contamination of the testing laboratory, etc., when other rooms in the building were treated with dieldrin for malaria control. Tests were confined to leaves; the bark of twigs was not tested.

CHEMICAL ANALYSES

After the test insects had been exposed, the insecticide was dissolved from the surface of each batch of ten leaves by shaking with 30 ml. of acetone for five minutes, after which the extract was poured slowly on to a folded sheet of blotting paper at such a rate that the evaporation of the acetone was sufficient to prevent loss of the extract through the paper. A second extract was prepared and absorbed on the same blotting paper, which was air-dried and sent to the laboratories at Arusha. The insecticide was extracted from each sheet with petroleum ether (B.P. 60° - 90° C.) in a Soxhlet extractor for two hours. The residues after evaporation of the solvent were treated with boiling alcoholic potash (for D.D.T.), or sodium and isopropyl alcohol (for dieldrin) [Robinson and Mesmer, in Press].

The area of each batch of leaves was measured by drawing round the leaves on a piece of paper, cutting out the paper leaves and calculating the area from the known weight/area ratio. From the chemical estimate and these areas the amount of insecticide per square foot was calculated. Spray was deposited on one side only of any leaf.

RESULTS

The results of the biological tests are given in Table I, the chemical estimations in Table II and Fig. 2, where smooth curves have been drawn by eye. The falling-off in the effectiveness of the Arkotone was spectacular. The initial dosage of D.D.T. appears to have been low; it should have been the same as that of the 5 per cent dieldrin, whereas it is only about two-thirds. Both should be about three times as heavily deposited as the 1.7 per cent dieldrin. In fact, the D.D.T. is 2.6 times and the 5 per cent dieldrin 3.9 times as heavy. If the original values taken from the smoothed curves are taken these ratios become 2.3 and 3.5 respectively. Thus the deposit of D.D.T. is lower than expected compared with either deposit of dieldrin. There was a very rapid loss of D.D.T. in the first three days and the

subsequent rate of loss was higher than was expected from previous work on persistence of insecticide on leaves. The normal curve for such a situation is shown by the Dieldrex treatments, particularly the 5 per cent mixture, and it appears that the Arkotine was subjected to a source of loss from which the Dieldrex was immune. Microscopic examination showed the Arkotine hold spread as a sort of varnish over the leaf, the crystals of D.D.T. being present as numerous clumps of needles standing clear of the surface, readily removable completely by rubbing. The Dieldrex appeared as a spongy, waxy, amorphous deposit covering small crystals, which could be seen in the holes of the sponge. When the Arkotine deposit was examined after 12 days, very few crystals of D.D.T. were visible although the varnish remained; whereas after three and a half weeks there was no apparent change in the Dieldrex deposit. There was heavy rain the night after the Arkotine and 1.7 per cent Dieldrex was sprayed, but this made no apparent difference to the appearance of the deposits. There was no more rain before the Arkotine became ineffective; but during this period there were several heavy thunderstorms in the vicinity, accompanied and preceded by violent winds, and it is possible that the shaking and rustling suffered by the leaves were sufficient to dislodge crystals of D.D.T., although the dieldrin crystals were sufficiently cemented to the surface to resist this process.

When the locality was visited after eight weeks, visible changes in the deposits had taken place. There had been much rain in the area meanwhile. The Arkotine deposit was much more obvious, as a white bloom, but there was no trace of insecticide under the microscope. The Dieldrex seemed unchanged on heavily dosed leaves, but there were many others which seemed clean or bore very faint white traces in the veins. Although some apparently clean leaves gave kills; it is likely that many light deposits had been entirely removed. It is also possible that there was some reduction in efficiency due to a coating of dust.

DISCUSSION

It is unfortunate that the Arkotine gave such a low deposit—only just over twice that of the 1.7 per cent dieldrin instead of three times. It seems unlikely, however, that an initial deposit some 50 per cent higher would greatly prolong the lethal effect. The actual deposit of 28 mgm./sq. ft. fell by one-third in about two days and this would be the net gain in effectiveness with the higher rate. Comparison of the two Dieldrex curves supports the assumption that rate of loss is the same for deposits of various amounts; since, in both, the initial deposit falls by one-third in about nine days, and, from about day 35, when 5 per cent dieldrin treatment has fallen to the initial level of the 1.7 per cent dieldrin treatment, the form of the curves is similar.

The question arises how an insecticide that loses half its effectiveness in about a week has eliminated tsetse flies when applied at two-weekly intervals. Firstly, it is likely that under milder conditions of exposure to sun, wind and rain, especially at higher rates of application, Arkotine will last longer than in our tests. Support for this supposition is provided by results obtained by K. E. Woodcock and quoted by Robertson (1956). It also seems probable that on twigs both insecticides will persist better than on leaves, but investigation of this was not made owing to scarcity of test insects. Further, in nature the flies are likely to settle for much longer periods than 15 seconds; but, since they probably move very little once settled, this is likely to be of less importance than movement from perch to perch, which will increase the chance of choosing a lethal resting place. Secondly, elimination can be achieved, even by a completely non-persistent insecticide, if it causes a high mortality each time it is applied and if applications are made at intervals short enough to prevent more than a small amount of breeding by survivors. This is the logical basis of treatment of tsetse habitats from the air (e.g. Hocking and Yeo, 1953). Even if Arkotine remains highly lethal for only two or three days, this may be sufficient to kill

TABLE I.—PERCENTAGE MORTALITY AMONG *G. palpalis fuscipes* EXPOSED FOR 15 SECONDS TO SPRAYED VEGETATION CORRECTED FOR CONTROL MORTALITY

Days after treatment	2	3	5	8	10	12	13	16	20	24	56	58	91	93
DDT 5% ..	..	89	66	50	..	6	..	..	..	..	..	..	..	..
Dieldrin 1.7% ..	87	96	96	88	88	92	100	100	100	56	67	92	100	94
Dieldrin 5% ..	..	..	..	..	..	..	..	..	..	90	92	92	100	94
Control ..	6	0	17	0	15	17	17	0	0	0	23	8	over 50%	{ (Known contamination)

nearly all the adult flies present at the time of spraying, and insects emerging later will be caught by the next spraying before they can breed.

If Arkotine has worked in the manner described above, the margin of safety between success and failure has been precariously small. In the conditions of our experiment the total lethal period covered by four two-weekly treatments would be about 50 days. Any survivors of the first treatment can oviposit in safety up to the fourteenth day of the campaign. Symes and Southby (1938), working in Nyanza, observed pupal periods among naturally deposited pupae of 44-52 days. Under similar climatic conditions the offspring of survivors of the first spray would continue to emerge up to the 58th-66th days after the initial treatment, and almost certainly escape destruction. Success in the past suggests that either the kill within two or three days of an application has approached completeness or that the insecticide has been more persistent than our results indicate.

TABLE II.—CHEMICAL ESTIMATES OF DEPOSIT; MEAN DEPOSIT ON 100 LEAVES AS MGM/SQ. FT.

Age of Deposit Days	D.D.T.	1.7% Dieltrin	5% Dieltrin
0 ..	27.6	10.6	41.6
2 ..		10.1	40.5
3 ..	12.7		
5 ..	10.4	10.0	
6 ..			24.4
8 ..	9.7		
10 ..		6.0	
12 ..	7.5		
13 ..		6.3	
16 ..		7.7	
20 ..		10.7	
23 ..			16.1
24 ..		7.9	
55 ..			7.2
56 ..		3.4	
58 ..		4.0	11.6
91 ..			9.9
93 ..			5.1

It is not possible to say what kill must be shown in contact tests of the sort here described for the treatment to achieve extermination in the field; but if we put it at 90 per cent it will be seen that Arkotine is effective for only three days (perhaps five days with a 50 per cent higher initial deposit—see above).

Dioldrex diluted to 1.7 per cent dieltrin lasts for well over three weeks, since the decline in mortality from three and a half to eight weeks is slow. This means that one application of 1.7 per cent dieltrin lasts at least three weeks longer than one at 5 per cent D.D.T. Four sprayings of D.D.T., two weeks apart and giving a total lethal period of about seven weeks, have been successful in the past. Therefore, two sprayings with 1.7 per cent dieltrin five weeks apart should be equally effective, since each application is lethal for three weeks longer than a treatment with D.D.T. Since in the past a total lethal period of only seven weeks has been effective, the interval between the two dieltrin applications may be fixed at four and not five weeks, giving a total effect of at least eight weeks and less chance of a falling-off in kill between the two treatments. In addition, the slow decrease in effectiveness of the dieltrin (kills were still 60 per cent after eight weeks) will give a long period of reduced but considerable lethality.

Alternatively, one application of 5 per cent dieltrin might be as effective as two of the 1.7 per cent emulsion. The safety margin might be less, owing to the complete loss of effectiveness of lightly dosed points after two months and the impossibility of reinforcing poorly treated areas, which is always possible when making more than one treatment. On the other hand there is such a gain in the amount of work one man can supervise that a slightly greater expenditure of insecticide and care in its application would more than compensate for this, at a great net gain. The cash saving will depend on the relative costs of insecticide and applying it. On the Nyando river scheme these approached equality, and the adoption of either routine would give a saving of about 50 per cent over four applications of 5 per cent D.D.T.; when large areas have to be covered, involving much travelling, the single application of 5 per cent dieltrin has much to recommend it.

It can be shown by calculation (Burnett, 1955) that, at the temperatures normally experienced in this area, four treatments with Arkotine at three-weekly intervals would be just as efficient as two-weekly treatments, with less chance of failure, since the total period covered by the operation extends to ten instead of seven weeks and so gives a better chance of catching the offspring of any survivors of the first treatment. If the kill at each application approaches 100 per cent, which is suggested by past successes (since

the total persistence of lethal conditions is so short), three treatments only, at three-week intervals, would succeed. It would be as well to test this on a practical scale before adopting it as a routine.

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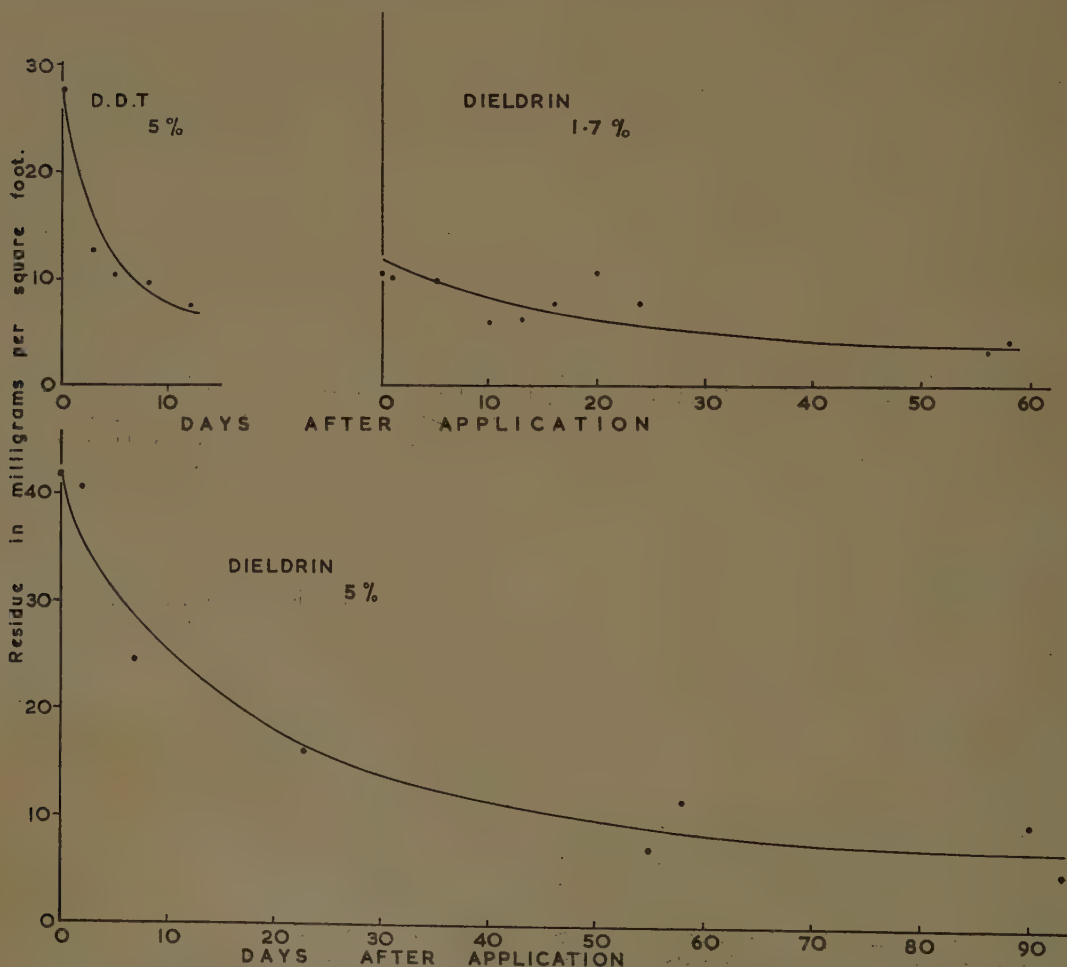


Fig. 2.—The decrease in insecticide deposits, chemically estimated, with time since application

THE INTERNATIONAL UNION OF FOREST RESEARCH ORGANIZATIONS

By A. L. Griffith, East African Agriculture and Forestry Research Organization

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The 12th Congress of the I.U.F.R.O. was held in Oxford in July, 1956, and was followed by a choice of eight study tours in the forests of the British Isles. It was attended by 242 delegates from 42 countries. It was a great pleasure to see the U.S.A. and Canada represented in force, and also that some of the iron-curtain countries felt able to send delegates, thus showing that the foresters of the world can get together and discuss common problems and that a world-wide science such as forestry can transcend politics.

The meeting of the actual conference sections in Oxford were staggered, so that it was possible to attend those subjects in which one was interested; but in general, General Forest Influences, Forest Plants, Forest Protection, Site Factors and Silviculture formed one half, while the second half covered Growth and Yield, Operational Efficiency, Forest Economics and Mechanical Conversion. Some idea of the extent of world interest in the conference is obtained from the fact that no less than 193 papers were submitted on the comparatively limited number of subjects that had been selected for discussion.

During the actual conference week we had an interesting excursion to the beech forests of the Cotswolds, and a choice of excursions to the Alice Holt Forest Research Station of the Forestry Commission, the Forest Products Research Laboratory at Princes Risborough and to the Rothamsted Agricultural Experimental Station.

After the main conference, we split up for the eight study tours, and I went to Northern Scotland. It may sound strange to go to the North of Scotland to see work of interest to East Africa; but there it was, and it was very interesting to see how allied the problems are. The main subjects of the tour were the introduction of exotic conifers, making the best of poor indigenous forests during the time of conversion and the afforestation of difficult sites, such as heathland, moorland, shifting sands and eroded areas. Other subjects of interest seen were the mechanization of nursery work, the use of fertilizers, weed control by volatile oils and the very important work going on in genetic research and the

raising of seed orchards. It was most noticeable that even in a well developed country like Great Britain they still have their worries over the ensuring of good, reliable seed supplies, and are realizing more and more how essential it is not only to raise the best species but the best strain of the best species. At the same time, it must be realized that Great Britain is not an experienced forest country like France, Germany, and Central Europe in general, which have been practising forestry for many centuries, for the Forestry Commission only dates from about 1920 as compared with the Forest Departments of Kenya and Uganda, which started in 1902 and 1903 respectively. Great Britain, however, has the money, the staff and the facilities for intensive research and is rapidly making up the leeway of neglect of forestry in the century before the Forestry Commission came into being.

An innovation of the Conference was that for the study tours, the Forestry Commission and all concerned had gone to great trouble to print detailed tour notes of all the projects visited. This meant that we could all read up what we were going to see beforehand, so that, when at the actual site, we could really see and discuss what was going on and we were not forced to try to see with one eye and hear with one ear while feverishly endeavouring to write Tour Notes. An interesting fact, not realized at first when thinking of the quick growth and short rotations of East African forest crops, is that, while the trees are growing, they grow at about the same rate in both East Africa and in the United Kingdom. The great difference is in the length of the growing season. Here, in East Africa, with our climate, with little or no differentiation between summer and winter, or the length of the day in summer and winter, our trees have no dormant or resting season, but continue to grow for 365 days a year, whereas in the United Kingdom the growing season is only some 120 days' long.

One of the great benefits of a conference such as this is the contacts that are made and the work that gets done "after hours". One meets one's opposite numbers from all over the world, and it is possible to establish

relations by personal contact that are impossible by correspondence. For example, we in East Africa are dependent on South Africa, the U.S.A., Mexico, Australia, New Zealand, etc., for our seed supplies and we, in our turn, supply seed to many countries. It makes a world of difference if one has met and discussed problems with those from whom one is asking for seed, or to whom one is sending seed.

I took the advantage of the conference, being in Oxford, to visit Paris *en route* and to discuss with the French Colonial Forest Service such problems as general tropical research, information, documentation and ledger filing, and the classification of African Forest Types. This was done at the Centre Technique Forestier Tropical at Nogent-sur-Marne, and was in effect part of the follow up of the Inter-African Forest Conference held in the French Ivory Coast in West Africa

some years ago, which I was fortunate enough to attend.

It was, indeed, a great privilege to attend such an international conference as that at Oxford; and from my own personal experience I cannot emphasize too strongly the uses and good that come from such meetings. A number of people hold the opinion that such conferences are a waste of time and money; but I have now attended two I.U.F.R.O. conferences, the Inter-African Forest Conference and a British Commonwealth Forest Conference in Canada, and I can assure readers that the benefits that accrue are well worth the time and money spent on them.

It is gratifying that the new President of the I.U.F.R.O., elected at this conference at Oxford, is Mr. J. Macdonald, who is the Director of Research and Education of the Forestry Commission of Great Britain.

REVIEW

USEFUL PLANTS OF NYASALAND, by Jessie Williamson, M.A. (Cantab.), Dip.Diet. (Lond.). The Government Printer, Zomba, Nyasaland. Price Sh. 15.

This book by Mrs. Williamson comes as a useful companion to *Useful Plants of West Tropical Africa* and deals as competently with the commoner plants of Nyasaland as the other with West Africa. Since many of the plants are found also in other parts of central and eastern tropical Africa, the value of this book will not be limited to the area in which it was compiled.

The author has devoted much time to a study of the African peoples of Nyasaland and the many uses to which they put the indigenous plants of their country—and many commonly cultivated ones as well. The size of this book is no indication of the amount of information that she has packed into its concisely written pages, for in only 126 pages we are given very full accounts of nearly 500 species. The plants described are arranged in alphabetical sequence of scientific names, a very convenient order for reference. The botanical name is followed by any English name or names the plant may have, and a number of native names together with the localities where these were collected. Then follows a rough description of the plant, often with notes on its habitat. Finally we have its uses: if as a timber, the reader is given

detailed notes on the purposes to which it is put and frequently its colour and graining as well; if as a medicine, the disease it is used for and the mode of preparation; if as a food, the method of preparation and whether it is used as a main dish or side dish and a note on other foods which are usually eaten with it.

The general appearance of the book is unfortunately spoilt somewhat by the illustrations, which, though well drawn, have become smudgy and uneven in the printing.

The classified index is a valuable reference in itself, with its sections on edible plants (divided into subsections according to the kind of food-stuff yielded), medicinal plants, woods, textiles and fibres, miscellaneous. This index gives only the scientific names; but the comprehensive general index, which we are also given, renders this of no real disadvantage. The author's notes heading the latter are a useful reminder on the variability of pronunciation and spelling in languages that are rarely written, and should prove a useful guide where the reader is seeking references to a plant whose native name does not at first appear to be included. In such cases, too, the description given of the plants will indicate whether the modified name, accepted by the reader as another form of the one he is looking up, is in fact the same plant or another with a similar-sounding name.

D. NAPPER.

THE SANGA CATTLE OF EAST AFRICA

By H. Epstein, Faculty of Agriculture, Hebrew University, Jerusalem

(Received for publication on 30th May, 1956)

THE CLASSIFICATION AND DISTRIBUTION OF THE EAST AFRICAN SANGA CATTLE

The humped cattle of Africa may be classed according to the situation of the hump: cervico-thoracic or thoracic. For convenience, the cattle with cervico-thoracic humps are called "neck-humped", those with thoracic humps "chest-humped". The neck-humped cattle are divided into zebu cattle, represented by the red Afrikaner of South Africa and sanga cattle, derived from zebu and humpless longhorn parent stocks. Similarly, the chest-humped cattle are classed into zebu and sanga. Thus African sanga cattle are of two different types: neck-humped and chest-humped.

In East Africa both sanga types occur. In Somaliland and Eritrea, close to the points of entrance of chest-humped zebus from South West Asia, the sanga cattle are of chest-humped type. South of the Zambesi, whither the range of chest-humped zebus does not extend, the sanga cattle are of neck-humped type. In the region between the Anglo-Egyptian Sudan and the Zambesi there is considerable variability in hump situation among and within different sanga breeds. A postage stamp from the Belgian Congo schematizes the distinction between the two types of sanga admirably.



Postage-stamp from the Belgian Congo, showing neck-humped and chest-humped sangas

In Italian Somaliland the sanga type is represented by the Jiddu which in its purest form is bred in the region of Ballei, at the

Juba river; it also occurs in the Juba districts of Goshia and Lugh, along the Benadir coast, and in the Rahanwihn territory—all in the southern part of Somaliland (Gadola, 1947). During recent years many Jiddu cattle have been brought from Somaliland to Kenya.

By some authors the Jiddu is classed as zebu; by others, mainly because of the very long thick horns encountered in many representatives of this breed, as sanga. This difference of opinion is due to the difficulty of drawing a clear line between breeds and individual specimens representing border cases of chest-humped zebu and sanga. This state is bound to continue until the various chest-humped sanga breeds of East and West Africa have been thoroughly studied from an osteological viewpoint and definite anatomical rules been laid down on which classification may be based. Until then—or in case such rules cannot be established in view of the large number of intergrading links—the break between the chest-humped zebu and chest-humped sanga will have to be made arbitrarily at some point of the chain.

In Eritrea the sanga is represented by the Arado sub-type which comprises a number of different local breeds. Its distributional area includes the entire high plateau along the Ethiopian border, the districts of Maria, Mensa and Sachel.

In Ethiopia the Arado is bred throughout the north-eastern territory contiguous with the Eritrean range of the type. Heck encountered it in the district of Diredawa, north-east of Addis Abbaba (Antonious, 1943-44).

Of the two principal cattle types of the Anglo-Egyptian Sudan, i.e. the sanga and the zebu, the zebu is bred mainly by Arab nomads north of about the ninth or tenth parallel N., the sanga by pagan Nilotic, such as the Nuer and some of the Dinka and Shilluk, south of this line. The approximate boundary of demarcation between zebu and sanga in the Anglo-Egyptian Sudan is formed by the rough east to west line which divides the northern Mohammedan from the southern pagan areas of human habitation. The negligible degree to which these two group types have mixed in historic times may be ascribed to the same causes that have kept the human inhabitants

of the two areas equally distinct (Bennett, 1938). Of the two stocks, the sanga is undoubtedly the older. It was pushed back behind its present northern boundary by the steady pressure of Moslem invasion that persisted throughout the Middle Ages.

In the south-western part of Ethiopia, contiguous with the sanga territory in the southern Anglo-Egyptian Sudan, cattle of sanga type are bred mainly by Nuer and Galla tribes.

From Ethiopia and the Anglo-Egyptian Sudan sanga cattle passed through Uganda and followed the Great Lakes southward to the Zambesi.

In Uganda sanga cattle—the Ankole or Usagala—are found in the Western Province, while the Eastern and Northern Provinces are occupied mainly by chest-humped zebu. A sub-type of the Uganda Ankole, the Bunyoro, is bred east of Lake Albert.

North-west and north-east of Lake Albert, zebu cattle form an intrusion, in fact break the continuity of the sanga line from the southern Anglo-Egyptian Sudan to the northern end of Lake Tanganyika (Curson and Thornton, 1936).

From Buganda and Ankole sanga cattle have been taken to Ruanda-Urundi and the shores of Lake Kivu, where they are grazed on vast stretches of fertile pasture at an elevation of from 5,000 to 6,000 feet above sea level. Lep'ae (1926) mentions that these cattle were introduced into this region by the Bahima, a pastoral folk that probably came from Abyssinia, about three or four hundred years ago.

Roughly, sanga cattle in the lacustrine part of East Africa are kept by the High Nilotic group of peoples, the Mittu, Madi, Abukaya, Abaka, Lebu, Wira, Lendu and Moru, and by the lacustrine tribes of the Eastern Bantu, the Baganda, Bunyoro (Bakitar), Karagwe, Waruanda, Warundi, Wasukuma and Wanyamwezi, who live on the northern and western shores of Lake Victoria and in the vicinity of Lakes Albert and Edward.

There is a great fly belt running south from Pasha Gulf to Lake Victoria. The fly-free country to the west of this belt is a strip of mountain grassland along the borders of the Belgian countries of Ruanda and Urundi. This is the home of the Ankole cattle, and it is contiguous with the habitats of the same breed in the Belgian territory and in Uganda. A few

herds of Ankole cattle are found on the eastern side of the Pasha Gulf-Tabora belt, but here they are in contact with and tend to be swamped by the more virile zebu. Whereas the Ankole is essentially an animal of mountain grassland, the zebu can adapt itself to almost every kind of vegetation; and the limiting factors of its distribution in Tanganyika are neither climatic nor geophysical, but simply tsetse-fly belts (Hornby, quoted by Curson and Thornton, 1936).

Ankole cattle are found in greater or lesser degree of purity along the north-western borders of Tanganyika in the Bukoba Province, bordering Belgian Ruanda and Urundi. They constitute less than one-fortieth of the herds of the country (McCall, 1928).

Formerly the distributional area of the sanga in East Africa seems to have considerably exceeded their present range. Orde Brown (1925), describing the tribes of Kenya, between Mt. Kenya and the Tana river, states: "There was, however, a breed of cattle which has now died out, which possessed far larger horns than the existing breed (zebu), and are said to have been finer animals in every way. They are said to have been very numerous, and to have been killed off in the epidemic of rinderpest, which occurred apparently about 1890; . . . There are no traces of these animals now left, except the horns, which are occasionally to be met with, made into drinking vessels; these nearly always came from Emberre".

The region lying between the southern end of Lake Tanganyika and the northern end of Lake Nyasa is believed to be the bridge through which sanga cattle were diffused from the north. For if the assumption that the native cattle of southern Africa have come from the north is sound, a path of diffusion must be found; and since there is continuous distribution from north to south only through this narrow strip of land, it may be safely assumed that this was the path of diffusion (Herskovits, 1926).

South of Lake Tanganyika the sanga stream is interrupted by the southernmost offshoot of chest-humped zebu cattle which occupy the country between Lake Tanganyika and the Zambesi river. In Nyasaland the chest-humped zebu, owing to its hardiness, has displaced the sanga. Similarly, in Mozambique, north of the Zambesi river, the cattle are mainly of zebu type, although one authority holds that sanga cattle still occur in a narrow

strip along the sea coast from the mouth of the Ruvuma to the Zambesi, where they join the main stream running southwards through the country of the Shona peoples.

In Northern Rhodesia the sanga type is represented by the Bechuana cattle in Barotse-land, and the Baila or Mashukulumbwe cattle between the Zambesi and Kafue rivers. "As the Zambesi river, constituting a formidable barrier to migration especially during the summer months, flows just south of the southern extremity of Nyasaland, it is probably in this vicinity that the Bantu hordes halted and subsequently dispersed in all directions, but chiefly south-east to west in a fan-like fashion" (Curson and Thornton, 1936).

The sanga cattle of Southern Rhodesia are of two different sub-types: the Bechuana or, as they are also called, Mangwato or Amabowe, and the Makalanga or Mashona (Matabele).

The Mangwato of Southern Rhodesia is found particularly in the south and west of Gwanda district, in the southern end of Bulalima-Mangwe, and across the border to the south of Tuli. This breed has contributed its share to the cattle of the Matabele, and was in existence long before the advent of that warrior race (Nobbs, 1927).

The distribution of the Makalanga cattle is, roughly speaking, limited on the north by the Zambesi valley, on the east by the Southern Rhodesia-Mozambique border, on the south by the Limpopo valley and the Devuli river, and on the west by the Shangani river. But sporadically Makalanga cattle may be met with beyond these boundaries. In the Union of South Africa a few specimens of the type are to be found scattered throughout the Northern Transvaal (Bisschop and Curson, 1933).

On the east coast of South Africa the sanga type is represented by the cattle of Swaziland and Zululand, now commonly called Nguni cattle, which extend from Mozambique into Natal. The cattle of the Northern Transvaal are of Bechuana origin. The distributional area of the Nguni cattle is, therefore, bordered on the north by chest-humped zebus, and on the north-west by the Makalanga and Mangwato sanga breeds.

Farther south there are several enclaves of purebred sanga cattle in a sea of nondescript grades. In Bomvanaland, in the district of

Elliotdale, there are two herds of sacred cattle—remnants of many similar sacred herds that existed at one time throughout the Transkeian Territories: one herd is kept at the kraal of Tyelinzima, chief of the Ama-Tshezi, the right-hand house of the Bomvana, the other at the seat of the reigning house, in safe keeping of Ngubezulu, the son of Gwebindlala, for his tribe of Ama-Bomvana. The herd at Tyelinzima's is named Ondongolo, and that belonging to Gwebindlala's family is named Bolowane or Zankayi. These cattle are traceable as far back as the year 1650, when part of the Bomvana tribe left Natal and settled in Pondoland owing to differences over the sacred Izankayi cattle. The Bomvana remained in Pondoland until the early years of the nineteenth century, when they were compelled to quit the country, and obtained permission from the Ama-Xosa to occupy the territory between the Bashee and Umtata rivers and along the coast south-east of Tembuland, the country now known as Bomvanaland.

Among the Ama-Xosa, located in the region of the Fish, Kei, Keismana and Bashee rivers, in the eastern part of Cape Province, the last remnants of sanga cattle are still found, very much mixed with stock of European derivation. The sanga cattle once kept by the rest of the Bantu tribes of South Africa have intermingled with cattle of European origin to such a degree that, in the words of Curson (1936), "the time has long passed for describing the indigenous cattle of the Cape, Orange Free State and Southern Transvaal."

CHARACTERISTICS OF THE EAST AFRICAN SANGA CATTLE

Sanga cattle vary in size from dwarfed breeds, as the Makalanga or Mashona, to large animals, as the Bechuana. The head is usually long, moderate in width, with a convex profile, as in the majority of the Nguni cattle, or a straight profile, as in the Bechuana (Bisschop, 1937). The horns vary greatly in length, basal girth and direction; polled sanga cattle are comparatively rare. Among the horned breeds two main types can be distinguished: one with long relatively slender horns; the other with gigantic horns of great basal circumference; basal girths of 22 inches and more have been recorded.

The vast majority of sanga cattle are humped. The tendency to be humped is more general than horn gigantism. In bulls the hump is more prominent than in cows; it is better

developed in some breeds, as the Bahima, than in others, as the Nguni or Barotse. Hump situation, as previously stated, varies. The typical sanga hump, as characteristic of all sanga breeds south of the Zambesi, whither zebu cattle with thoracic humps have not penetrated, is cervico-thoracic. North of the Zambesi line, few sanga breeds have remained unaffected by chest-humped zebu stock which, during recent centuries, has spread throughout Africa south of the Sahara at a phenomenal speed. And, as Gates (quoted by Mason, 1951) has pointed out for West Africa, the greater the proportion of zebu blood that is evident, the larger and farther back is the hump.

The shape of the hindquarters of the sanga cattle varies considerably. The Nguni and Makalanga breeds have the sloping rump, low-set pin bones, rounded upper thighs and the long narrow gaskins typical of zebu cattle, while the Bechuana exhibit a straighter rump and better let-down thighs (Bisschop, 1937).

The bifidity of the spinous processes of the thoracic vertebrae typical of zebu cattle is generally found also in sanga cattle; but in these the cleft varies in depth and is usually less pronounced.

The Jiddu or Surco of Italian Somali land reaches a withers height of 124-140 cm. in the male, 122-127 cm. in the female. The head is large, with a straight or convex profile. Commonly the horns are long and thick, lyre-shaped with the tips bent forwards or backwards, or sickle-shaped; their length along the curve is approximately 90 cm., the basal girth 42 cm. In some specimens, closely akin to the East African zebu, the horns are of medium size. The ears are fairly long, the eyes rather small. The dewlap is very prominent, the chest often constricted, only occasionally well filled in bulls of a high quality. The hump is of moderate size. The anterior part of the body is long, the lumbar region of the back fairly short and straight, the slightly drooping rump short but wide. The legs are well proportioned, the upper thighs well muscled, the hoofs strong. The hide is thick and heavy; the hair commonly red in colour, with white, yellow or grey spots (Gadola, 1947).

The Arado or Beri of Eritrea and the adjacent territories of Ethiopia, comprising a number of breeds differing in body size and proportions, is either long- or giant-horned, rarely devoid of horns; occasionally the horns

swing freely at the sides of the face, owing to the absence of cores (Masoero, 1938). Generally the Arado shows sufficient depth of chest, a well-developed dewlap, drooping rump, and large heavy hoofs. The thoracic hump is large in the bulls, less developed in oxen, hardly noticeable in the cows. At the end of, and immediately after, the dry season the humps of bulls and oxen also shrink to a minimum. Calves have tiny humps until they reach the age of one or two years when their humps begin to develop (Marchi, 1929). The thick hide of the Arado offers protection against the cold climate of the high plateau. In its resistance to cold and its great capacity for work the Arado is superior to the small Begait and Araba zebras of Eritrea, which are neither resistant to the hardships of the mountain climate nor capable of strenuous work.



Arado bull. After Gadola

The Arado cattle of the Mareb river region are known by the name of the Galla, their native owners. The Galla Arado are giant-horned forming the transition to the Ethiopian Galla sangas, some of which are distinguished by immense horns. The Tigre and Baqqara breeds, included by Italian authors in the Arado sub-type, are so much influenced by East African zebu stock that the majority may be classed as zebu rather than sanga, although most of them still have fairly large and thick horns. While in the Galla Arado the forehead is broad and flat, in the Tigre it is very narrow, especially between the horn bases. Again, in the Galla the facial part of the head is relatively short, in the Tigre long. In these respects the Baqqara cattle resemble the Galla rather than the Tigre Arado. In all Arado breeds the ears are of minimum size and semi-pendulous. The size

of the body depends to a considerable extent on environmental conditions. The prevalent colours are red in different shades, red-and-white, and black-and-white; uniformly grey, black, brown or white specimens are less frequent. Only in *Maria Rossi* the majority of the Arado cattle are black, a colour held to offer better protection against cold than red which, on the other hand, gives superior protection against the rays of the sun (Marchi, 1929).

Beyond the Mareb river the Arado cattle represent a mixture of different types, some small, others large. The large-framed Arado cattle from Hamasen and Libam are in great demand. But the cattle from Waira and Mensa, and especially those from Habab, are very small and slender and little valued. They are predominantly zebu, with only a slight admixture of humpless longhorn and possibly also of shorthorn strains. Their horns differ in shape and size. Some have very long horns, others medium-sized, still others are short-horned or polled. Animals with one or both horns loose are also encountered. The larger type is suitable for work and beef production. The average withers height is 118 cm., the height at the summit of the hump 120 cm., rump height 125 cm. (Gadola, 1947).



Giant-horned sanga from Southern Ethiopia.
After Keller

Among the Galla cattle of the south-western districts of Ethiopia two different types are distinguished: one in the Woina Dega, above 5,000 feet, the other in the Kolla, up to 5,000 feet above sea level. The highland cattle are larger than those of the valleys, and for the major part black, as their breeders prefer this colour in the cold mountain climate. Their

horns are approximately 16 inches long and 3-3½ inches basal girth (Keller, 1896). The hump is small, the dewlap well developed. The cattle of the Kolla are heavy-framed, short-legged and considerably smaller than the highland cattle. Their colour is white, grey, brown, black or black-and-white, occasionally red-and-white. The horns reached a tremendous size. In the mature animal each horn may hold 4 or 5 gallons of water. A pair of Abyssinian sanga horns, presented to the Museum of the Royal College of Surgeons by the traveller Salt, measures 45 inches in length, 15 inches in basal circumference, and 40 inches tip-to-tip distance (Adametz 1895). But this is by no means a record; some horns measure 48 inches in length and 21 inches in basal girth.



Dinka Cattle. After Schweinfurth

The sanga cattle of the southern part of the Anglo-Egyptian Sudan had originally small cervico-thoracic humps. Through infiltration of zebu cattle from the north and east a number of sanga breeds are now furnished with thoracic humps. The Dinka cattle, drawn by Schweinfurth 90 years ago, have thoracic humps and long slender lyre-shaped horns. In areas adjacent to chest-humped stock, chest humped specimens sporadically occur also in sanga breeds normally neck-humped. Breed characteristics have become inextricably confused by a few decades of relative intertribal peace and wide freedom of movement (Bennett, John and Hewison, 1948). The sanga cattle of the Anglo-Egyptian Sudan are usually greyish white in colour, sometimes which with black spots, occasionally red or red-and-white.

The cattle of the Nuer, south of the White Nile, are largely heavily-built beasts, with

lyre-shaped horn of great size, inclined markedly forwards with a slight backward sweep of the tips. The forehead is dished, the hump small or of medium size, and the colour of the coat generally variegated (Lydekker, 1912).



Nuer Ox. After a photograph in the British Museum

Certain Nilotic tribes, as the Dinka and Nuer, but not the Shilluk, practise artificial deformation of the horns of their cattle, a custom believed to be of ancient Egyptian (5th Dynasty) origin. Among the Dinka the usual deformity is with the one horn forwards, the other back; among the Nuer one horn is trained to grow upwards and slightly backwards, the other brought in a curve forwards across the beast's forehead. Cattle with artificially or naturally deformed horns have a social and emotional value, and the interest in such beasts extends far beyond the Nile region into Kenya, where it is known among the Suk (Seligman, 1932). In Northern Rhodesia "horns that hang down and swing or that are otherwise distorted excite high admiration" (Smith and Dale, 1920). In South Africa artificial deformation of the horns used to be practised by several Bantu peoples, as reported by many early travellers.



Long-horned sanga cattle from the Upper Uele. After Leplae

The cattle in the northern part of the Belgian Congo have for the greater part been imported from the regions adjacent to the northern frontier. Therefore they are akin to the Dinka cattle. The cattle of the Buta, in the country of the Ababua, in the northern district of the Belgian Congo, resemble the Dinka cattle of Bahr-el-Ghazal and Wadai, from which they are descended. This similarity refers to conformation as well as cranial characteristics. The horns of the Buta cattle are generally dark-coloured and of medium length. Leplae (1926) distinguishes between three different types of cattle in the region of the upper Ituri and Uele rivers. The first is polled, of small body size, fairly good dairy qualities, and easily fattened; this type is rare, being little valued by the natives. The second, which is the most common, carries horns of medium length and a well-developed hump. The coat is red, black or variegated, the body larger in size than in the polled type, and superior in conformation; but in its dairy qualities this type is generally very poor, with the exception of the cows in the herd selected by Chief Blukwa. These cattle, called Nioka, are derived from a mixture of sanga cattle and East African zebu. The third type has long horns and is very large, standing 130 to 140 cm. at the withers. The coat is white or reddish in colour, the body long and narrow, the chest fairly deep, the dewlap well developed, and the hump small. The milking qualities of the cows are negligible.

Leplae's classification of the cattle from the upper Uele and Ituri rivers is criticised by Curson and Thornton (1936): "Classification of cattle types in Congo", these authors write; "has been based largely on the absence or presence of horns and in the latter case, whether they are long or short. While the horn length is an important feature, it seems preferable also to consider the general conformation, especially the shape of the skull and the position and structure of the hump. As an example we may mention the cattle of Kivu, which vary not only to the extent of possessing polled as well as horned representatives, but also among the latter in having members with short, medium and long horns. Yet if we group these animals according to conformation they are seen to belong to the sanga type there being a uniformity in all respects except the horns."

South of the Anglo-Egyptian Sudan, in the lake district of East Africa, the sanga cattle

are known by the names of Bahima, Watussi or Ankole. These cattle are of medium size, commonly red or brown in colour, with dark muzzles. Lydekker (1912), quotes the Ankole cattle as an instance of sex dimorphism in colour. But this is a doubtful example, as not all Ankole bulls are white, nor all females red. The coat is short, dense and glossy, the hump only moderately developed, particularly in cows and oxen; occasionally it is completely absent. Curson and Thornton (1936) describe these cattle as follows: "The Ankole breed has a small hump approximating to that of the Afrikaner. It is without distinct coloration, so that specimens of every ordinary colour common among cattle may be found.



Giant-horned Ankole Bull and Polled Cow. After McCall

Nevertheless whole-coloured reds, browns and yellows definitely predominate. Polled animals form a very small minority of the Ankole cattle and are not liked. The horns are in every way an important feature of this breed, and individual animals are known by the shape of the horns. It is possible to divide the Ankole breed into local races which vary in size of horn: one, the Ishesha, has horns resembling and no larger than the Afrikaner's; but other races have enormous horns which, typically, grow outwards, upwards and backwards." The bones of the skeleton are thin and fine, and the leg muscles poorly developed. The ribs stand far apart. The udder is very small, and the milk production, as in many other sanga breeds, negligible. McCall (1928) records the following measurements and weight of an aged Ankole bull:

Height at shoulder		52 inches
Heart girth		68 inches
Live weight		850 lb.

The most characteristic feature of these sanga cattle is their tremendous horns, which are equally well developed in cows and in bulls. Owing to the powerfully developed horn cores and the tremendous horn necks, the head appears pointed orally. The profile is slightly convex because of the great discrepancy in development between the neurocranium and splanchnocranium. The forehead is flat. The horn cores are of tremendous dimensions. Their diameter measures approximately 5 inches, the basal girth 15 inches. They are almost completely round, relatively smooth and slender, and in spite of their great size very light, being practically hollow. They are deeply furrowed and pearly at the bases. The horns, light-coloured with black tips, are 40 to 50 inches long, with a basal girth of 18 to 20 inches. The horn substance is rough and fibrous. The horns are either sickle- or lyre-shaped; in some animals they point sideways and upwards, with the tips slightly backwards and inwards. A strange anomaly, hornlessness is seen among herds of this breed, and manifests itself in the occasional appearance of polled specimens. Very seldom is a compromise met with; the animals are either beasts of abnormally long thick horns, or are completely devoid of even a vestige (McCall, 1928). Duerst (1899) distinguishes between two different types of Bahima cattle according to the shape of the Torus frontals. In the one type the intercornual line is concave, while the frontals bulge out in the centre; in the second type the frontal ridge is straight, and the frontals are flat. From Duerst's own subsequent studies on the horns of the Cavicornia (1926) it is evident that the above differences in the shape of intercornual line and the frontals cannot be explained on racial grounds, being ascribable to the effects on the skull of individual differences in the shape and direction of the horns, i.e. their moment of rotation.

In Uganda a herd of Ankole cattle is being established at Mbarara Livestock Farm for selective breeding and comparison with purebred zebu, while a polled dual purpose herd of crossbred Ankole and East African zebu (Nganda) is maintained at Entebbe with a view to evolving a fixed breed. Similarly, in Tanganyika it is planned to investigate the potentialities of the Ankole sanga and of Ankole and East African zebu crossbreeds at the Western Province Pasture Research Station (Faulkner and Brown, 1953).

Among the Bahima cattle of Lake Kivu, Ruanda and Urundi, Lep'ae (1926), on the lines of his classification of the sanga cattle from the upper Ituri and Uele rivers, distinguishes three varieties in accordance with the size or absence of the horns. The polled variety, few in numbers, is distinguished by a satisfactory conformation and fairly good milking qualities. The second variety, most numerous among the Wanyabongo, especially in the vicinity of Ngwese, is short-horned, and larger in size than the polled type; the colour of its coat is black, red or variegated, and the conformation even superior to that of the polled type, while the cows are considered good milkers. These cattle are of the Nioka type—crossbreds of Ankole and East African zebu. The third variety, found chiefly in the vicinity of Ruanda and Urundi, carries huge horns, but the general conformation is unsatisfactory, the body poorly muscled, and the milk yield of the cows small. The native owners value only the immense size of the horns, neglecting all other purposes of their stock. The sacred Nyambo cattle of the king of Ruanda are of this type.

Lep'ae's classification of the Kivu, Ruanda and Urundi cattle, based mainly on the absence or presence of horns and in the latter case on their length, is as little satisfactory as his classification of the upper Ituri and Uele cattle along similar lines. For in Kivu herds polled, short-horned, medium-horned, long-horned and giant-horned cattle are now to be found side by side; but the different specimens are not distinguishable in any respects except the horns. It is, however, possible that formerly these types were more clearly defined, and bred by different tribes in different localities.

Carlier (1912) mentions that the natives of the Kivu district consider the short-horned variety of their cattle to be indigenous, and the giant-horned to have come from Ruanda. The polled variety is believed either to have been imported by Arabs, or to have arisen spontaneously among herds of horned stock. As one does not commonly find more than one or two polled beasts in a herd of horned cattle, it would appear that the polled animals do not constitute a separate variety.

Kivu cattle with huge horns are frequent on the northern shore of Lake Kivu, on the foothills of the Virunga volcanoes. In the south this type is met with mainly among the Warundi and Wawira, occasionally among the

Wanyabongo. It is identical with the giant-horned Watussi (Bahima), and Kolbe (1914) assumes that it was brought to the Kivu district from Ruanda. The length of the horns varies between 70 and 110 cm.; sometimes the horns are so huge that the animals suffer serious incommodation. The Warundi and Wawira consider such horns beautiful, but



Cranium of Giant-horned Kivu Ox. After Lep'ae

the Wanyabongo do not hold them in favour, because the cows of the giant-horned variety are regarded as poor milkers and the type is hard to fatten. The shape of the horns differs: there are U-shaped and lyre-shaped horns; some spread outwards, others backwards or forwards. Sometimes the horns grow downwards, and occasionally they may be entirely devoid of cores and therefore loose. Short horns appear to be dominant to huge horns. The head of the giant-horned type is small, pointed and somewhat degenerated owing to the enormous horn development. The entire cranium is deteriorated, the bony material is very weak, and the weakness of the whole skeleton is not made up by a better muscular development. The animals are almost always in a very poor condition, except on the rich pastures of the volcanic district. The conformation of their bodies is very unsatisfactory. The neck is short, the chest flat, the back weak, the rump drooping, and the legs are weak. From an economic aspect this type is the poorest in the whole Kivu district.

The Rusizi sanga, to the south of Lake Kivu, excels the sanga cattle in other parts of Kivu in weight, conformation and milk production. Under good management Rusizi bulls exceed 500 kg. in liveweight (Tondeur, 1955).

In Ruanda-Urundi wealthy tribal chiefs occasionally keep herds of a uniform coloration—red, white or variegated (Kroll, 1928). This custom, known also among several Bantu tribes of southern Africa, is traceable to Ethiopia where it may have originated.

The sanga cattle of Katanga-Lomami, in the southernmost part of the Belgian Congo, have been imported from Northern Rhodesia since 1905. These cattle are of two different breeds: the Barotse, large beasts with huge horns, and the Mashukulumbwe, medium-sized animals with horns of medium length (Leplae, 1926).

The Barotse and Baila cattle of Northern Rhodesia are characterised by cervico-thoracic humps, sometimes ill-defined, and lyre-shaped horns. Coat colour varies greatly. Chief Lewanika of the Barotse people maintained a herd of pure white cattle with black points. These were all slaughtered when Lewanika died in the year 1916 (Curson and Thornton, 1936).



Skull and Horns of Barotse Ox

The Barotse cattle, a local variety of the Bechuana, are clearly divisible into two groups: the West or Plains cattle with gigantic horns, and the East or Forest cattle with long horns. Livingstone (1857) gives the following account of the Barotse cattle north of the Chobe river: : "They stand high on their legs, often nearly six feet at the withers, and they have large horns." Chapman (1868) describes them as "immensely tall and lanky . . . rather higher than an Afrikander ox, with immense

horns." Curson (1934), refuting a statement in the Annual Report of the Department of Animal Health, Northern Rhodesia, (1930), in which the Barotse cattle (prior to 1915) are referred to as "moderately tall, big horned and non-humped", says: "It is certain that the description 'non-humped' is an error, for all pure indigenous cattle in the Sub-continent are humped, the hump in many cases being exceedingly small."

The Baila, Mashukulumbwe or Tonga cattle, it has been suggested, are derived from a Bechuana sanga and Angoni zebu cross. But this is not likely, as the hump of the Baila is cervico-thoracic in situation, whereas the Angoni zebu has a thoracic hump. Baila cattle are suitable for beef production; at the Central Research Station, Mazabuka, two grass-fed Baila oxen, weighing 872 and 781 lb., had dressed weights of 437 and 440 lb. respectively. They make excellent trek oxen, whereas the Angoni zebu is not much good for this purpose. The Baila has a high immunity against tick-borne diseases, and may be partly resistant to trypanosomiasis (Curson and Thornton, 1936).

The Bechuana or Mangwato or Amabowe cattle of Southern Rhodesia are generally distinguished by small cervico-thoracic humps and huge horns. Nobbs (1927) describes them as follows: "Mangwato cattle are large-framed, the fat oxen averaging 600 lb. dressed weight. They stand on long, strong limbs and carry very wide-spreading thick, heavy horns. They make heavy, powerful trek oxen of great endurance, and the carcass is of good shape and quality, though maturity is only reached at eight or nine years. The cows yield, as native breeds go, a good quantity of rich creamy milk, and generally furnish about ten calves. They show a resistance to the common diseases, and probably possess some degree of inherited immunity. Red or red-white colours predominate though most colours are found, and they show that fixity of type which is characteristic of long-established breeds."

Some Bechuana cattle have horns similar in shape to those of the Bahima sanga; but more often the horns grow sideways with only the tips pointing upwards. In oxen the horns attain enormous dimensions, the tip-to-tip distance recorded in some of them being fully 8½ feet, and the length of single horns between four and five feet. Darwin (1868) mentions a distance of 8 feet 8¼ inches between the tips, and a total span of 13 feet 5 inches along the

curve in a Bechuana skull. In a Bechuana-Batawana beast the following measurements were taken: length on the outside curve of the horns $81\frac{1}{4}$ and $78\frac{1}{2}$ inches respectively, basal circumference $18\frac{1}{4}$ inches, tip-to-tip distance $103\frac{1}{2}$ inches. The greatest basal girth of the horn of a Bechuana ox so far recorded appears to be $19\frac{1}{2}$ inches (Curson, 1934).

Among the Bechuana cattle, as among other breeds of sanga, ordinarily long- or giant-horned, individual specimens are occasionally either short-horned or polled. North of the Zambesi short horns or hornlessness in sanga cattle have in most cases to be ascribed to the influence of East African zebu. In others, such as the few polled Ankole cattle, hornlessness seems to be due to spontaneous variation. This probably applies to polled specimens of the Bechuana breed. With regard to short-horned Bechuana cattle, Curson (1934) writes that this character "may also be attributed to the persistent introduction of pure-bred European bulls by Khama and other Chiefs."

The Makalanga or Mashona cattle of Southern Rhodesia represent the dwarf in South African cattle, mature cows standing about 95 cm. at the withers. Although small, the Makalanga is generally well proportioned and sturdy. The animal is fine of bone, with a shapely head, moderately long neck, rather rough sloping shoulders, fine withers, a prominent chine, goose rump and narrow quarters. The hump is small, well attached, and placed well in front of the withers. The dewlap is on the light side and devoid of filling. The head of the Makalanga is broad in the face, neat in the muzzle and lean in the cheek; the eye is prominent, large and intelligent, and very different from the small sunken protected eyes common to zebu cattle. The horn is circular in section and from 18 to 24 inches long. It usually sweeps upwards, tapering to a very sharp point. Makalanga cattle are of every colour, except roan and brindle. The preponderating colour is black; red, red-and-white also black-and-white in various combinations are common, while black-and-tan, merging into each other, is likewise a very frequent and characteristic coloration (Bisschop and Curson, 1933).

South of Mashonaland the cattle of the Matabele originate from the blend of many stocks and are a mixture of many sanga breeds, the enumeration of which reflects the history of the Matabele nation. Nobbs (1927) notes that: "they are of a very mixed deriva-

tion, so recently collected and amalgamated that the original types are known and distinguished, and they possess no common characteristics distinguishing them as a breed.



Nguni Cow

The Zulu and Swazi cattle collectively called Nguni, are of the same breed, the Swazi being but an offshoot of the Zulu. Variations in size and conformation observed among Nguni cattle in different parts of Swaziland and Zululand are attributed to the influence of regional environmental differences. The Nguni is adapted to the humid-hot climate typical of its semi-tropical breeding area.

The Nguni is a small to medium sized breed; bulls average 1,100 lb. liveweight, cows 750 lb. The head is deep and broad; long and narrow heads are found only in animals of inferior constitution. The forehead is straight and the face straight to slightly convex in profile. The eyes, because of less heavy arches, appear bigger than in zebu cattle. The ears are small and pointed. The horns are lyre-shaped, fairly long, slender, and round in cross-section. Polled cattle are rather frequent. In body build the breed displays harmonious proportions and tends more to the respirative than the digestive type, being wedge-shaped and somewhat narrow between the shoulder points and thirls, but with good length and curvature of the posterior ribs and good depth and capacity. Nguni cattle have excellent limbs and bone, but the neck and shoulders are rather light and the rump is short and drooping. In bulls the hump is well developed; in females, even when in good condition, it is small. Its situation is cervico-thoracic, and the structure purely muscular. The dewlap is thin and fine. On account of the moderate size of the dewlap and umbilical fold and the firm

hide, the general skin surface area of the Nguni, in relation to its body weight or volume, is appreciably smaller than in zebu cattle (Bonsma *et al.*, 1950). The coat of the Nguni is short, fine and glossy. Several whole colours occur in the breed: white, black, brown, red, dun and yellow. Black cattle play an important part in the ceremonial life of the Swazi. White cattle with an unpigmented skin are rare, but white in combination with a pigmented skin is seen fairly often. The Zulu Chief Cetewayo used to confiscate white cattle; their descendants are still kept at the kraal of the Paramount Chief of Zululand at Nongoma (Faulkner, 1947). In addition to whole colours, mixed colours in different patterns and intensities are very frequent. The majority of purebred Nguni cattle have pigmented hides (Bonsma *et al.*, 1950).

A herd of 500 Nguni cattle is maintained at the Mpisi Experimental Farm near Bremersdorp, Swaziland, for research and breeding work, more especially for comparison with Afrikaner cattle. A small herd has been established at Vuma Experiment Station near Eshowe, Zululand. Another herd of Nguni cattle is being maintained under research conditions in Portuguese East Africa.

The Bolowane cattle of Bomvanaland vary from red to dark brown and dun in colour. They are inclined to be small; and most of them are polled or have short horns pointing downwards. The structure and situation of the hump are typical of the sanga cattle south of the Zambesi. Bolowane cattle are employed for ploughing and draught, and also for racing purposes. The cows are poor milkers. The principal use of the breed is for sacrifice in times of calamity (Thompson, 1932).

The cattle of the Ama-Xosa, of the eastern group of the Southern Bantu, are an off-shoot of the Nguni, but, as previously stated, much mixed with European stock. Commonly they are distinguished by the flat barrel, long legs, and long horns variously curved; occasionally the horns are devoid of cores or entirely missing. Pendulous horns are often a deciding factor in the selection of breeding stock. Bulls are furnished with a prominent cervico-thoracic hump; in oxen the hump is smaller, in cows nearly non-existent. Xosa cattle are of a hardy type, suitable for transport purposes, but poor in beef and milk production. The variability in colour is remarkable; Soga (1931) lists twenty-five Xosa terms for different colours and colour combinations in cattle.

Formerly the Ama-Xosa kept a number of sacred herds in connection with religious worship.

THE DESCENT AND ORIGIN OF THE EAST AFRICAN SANGA CATTLE

The sanga cattle of East Africa are a section of the great sanga branch that extends from South and South West Africa northwards to the highland of Ethiopia. They are the remnants of a once ubiquitous type distributed over the whole of eastern Africa before short-horned zebu cattle made their appearance on the east coast. This is illustrated by Orde Brown's (1925) reference to the former occurrence of giant-horned sanga cattle in Kenya, as well as by the early introduction of sanga cattle from the east coast of Africa into the island of Madagascar (Keller, 1896).

The great variability in general conformation, cranial character, size of horns, and situation and structure of hump renders it probable that the sanga cattle are derived from different ancestral stocks.

As the two original basic types of African cattle, i.e., the longhorn (*primigenius*) and the shorthorn (*brachyceros*), are devoid of humps, the humps in sanga cattle cannot be derived from one of these two stocks. And since an independent evolution of the cervico-thoracic and thoracic humps in African sanga cattle may be ruled out as improbable, in view of the presence of humped zebu cattle in Africa south of the Sahara, the zebras remain the only source to which the sanga humps are traceable.

The zebu cattle of Africa are of two different types: (1) The Afrikaner (zebu) cattle of South Africa, furnished with well-developed cervico-thoracic humps; (2) the zebu cattle of East and West Africa, distinguished by thoracic humps (Epstein, 1955, 1956).

Zebu cattle with cervico-thoracic humps began to enter Africa nearly two thousand years earlier than zebu cattle with thoracic humps. Before their arrival, the cattle of Africa south of the Sahara, including East Africa south of the Nile valley, were mainly of humpless longhorn stock, as demonstrated by numerous rock paintings and engravings of cattle from this early period. The interbreeding of neck-humped zebu cattle with humpless longhorn stock in East Africa, more especially in Ethiopia, introduced the cervico-thoracic hump into the progeny. The variability in the size of the cervico-thoracic sanga hump, and

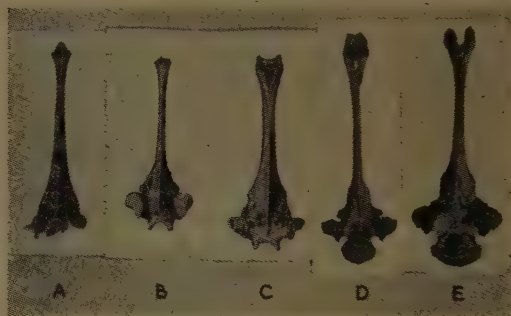
the complete absence of the hump in individual specimens of commonly humped sanga breeds, may partly be attributable to genetic segregation in a mixed type derived from humped zebu and humpless longhorn parent stocks. Curson and Bisschop (1935) have pointed out that the cervico-thoracic hump of sanga cattle resembles the Afrikander (longhorned zebu) hump in situation and structure. "The similarity of the humps of the Afrikander and sanga types, being cervico-thoracic and muscular, is noteworthy," these authors write, "in view of Epstein's theory that the latter is derived from the intermixture of the longhorned zebu and Hamitic longhorn. The dissimilarity between the above humps and that of the shorthorned zebu is striking."

Zebu cattle with thoracic humps have been introduced into East Africa from approximately the seventh century A.D. Owing to their superiority in functional properties to the humpless longhorn and neck-humped sanga cattle of Africa, the newcomers have rapidly extended their range from the points of entrance. Over wide areas in East Africa the chest-humped zebu type has completely superseded the sanga cattle; in others new breeds and a new type have arisen from their intermixture with neck-humped sanga or humpless longhorn cattle, a type in many respects similar to the original sanga, but differing in the situation of the hump which under the influence of chest-humped zebu has become thoracic. How far the structure of the hump has been affected by the chest-humped zebu component is still a matter of dispute.

In the chest-humped sanga breeds zebu features generally predominate over traits derived from the humpless longhorn ancestry, as may be expected in a cross consisting commonly of two different zebu strains to but one of longhorn.

Zebu cattle, those with cervico-thoracic and those with thoracic humps are distinguished by the bifid tips of the spinous processes of the anterior dorsal vertebrae. In humpless longhorn and humpless shorthorn cattle the neural spines are generally single. In sanga cattle with cervico-thoracic humps the spinous processes of the anterior dorsal vertebrae display considerable variability. In some the fissure is moderately deep, although commonly not quite so deep as in zebu cattle; in others it is hardly perceptible; and even within one and the same breed the differences are considerable. The variability of this character in

neck-humped sanga cattle supports our contention that these are derived from a mixture of zebu and humpless longhorn stocks. In chest-humped sanga cattle the neural spines of the anterior dorsal vertebrae have not yet been studied; therefore it is unknown whether they are generally bifid or of variable conformation. However, in the skeleton of a chest-humped Madagascar cow in the Onderstepoort Collection—a breed held to be derived from a mixture of African sanga cattle and Indian zebras (similar to the ancestry of chest-humped sanga cattle)—the neural spines of the dorsal vertebrae are distinctly bifid. Also, they are long and slender, markedly compressed antero-posteriorly, and distinctly curving backwards, as are the respective neural spines in purebred zebu cattle (Epstein, 1955a).



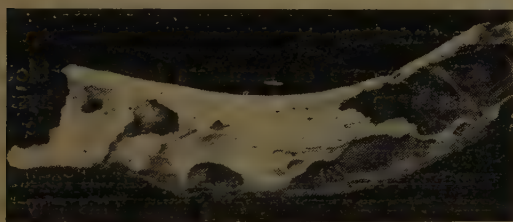
Ninth Dorsal Vertebrae

A=West African Shorthorn (*Brachyceros*) Bull,
B=Ovambo (Sanga) Cow, C=Zulu (Sanga) Ox,
D=Madagascar Cow, E=Afrikander (Zebu) Cow

The cranial character of sanga cattle varies greatly. In some the cranium is long and relatively narrow, coffin-shaped, with the convex frontals and receding forehead characteristic of the typical zebu. This skull conformation is more frequent in sanga breeds with thoracic humps; but it is by no means restricted to these, and it occurs also in sanga cattle with cervico-thoracic humps, as among the Nguni cattle. In other sanga breeds, such as the Bechuana, the cranium more often shows pronounced longhorn (primigenius) character. With regard to the Ankole sanga of East Africa, Antonius (1943-44) writes: "Among the giant-horned cattle of the lake district . . . we can recognise along with pure primigenius types—in head formation and top line—also those showing distinct zebu influence." Again, the primigenius skull conformation is not limited to sanga breeds with cervico-thoracic humps, although in these it is commoner. It is encountered also in chest-humped breeds in East Africa. This variability in cranial type has misled several

authors to present opposite extreme generalisations with regard to the racial character of the sanga group. While Stegmann von Pritzwald (1924) regarded the sanga cattle as of pure zebu stock, Antonius (1922) classed them with the *primigenius* type.

The horns of sanga cattle vary enormously in length, shape and basal circumference. This applies to the neck-humped as well as to the chest-humped type. In giant-horned sanga cattle the cores are often hollow and of such a porous material that they may not exceed those of long- and slender-horned animals in weight.



Horn Core Fragment of Giant-horned Sanga

Various interpretations of the cause of megalocery in the sanga cattle of Africa have been offered. Adametz (1920) suggests that it is derived from the African *urus*, a skull of which, with gigantic cores, was found in the Fayum. But the validity of this theory is doubtful; for megalocery was not restricted to the African race of the *urus*, but occurred among the European and Asiatic *urus* races as well. Moreover, the porous structure of the cores and the tremendous basal circumference characteristic of the horns of many giant-horned sanga cattle did not occur in the *urus*.



Rock Engraving of Giant-horned Bull from Assuam. Roman Period. After Schweinfurth

In Egypt giant-horned cattle seem to have been unknown; had they existed, the artists of the Nile country would doubtless have preserved their memory in sculptures and paintings. But in the deserts to the west and east of the Nile, and in Ethiopia, ancient rock

drawings indicate that Hamitic pastoralists at an early time evolved a giant-horned type from their longhorn stock. The humpless Kuri cattle of Lake Chad, distinguished by enormously thick bulbous horns, and the Buduma cattle in their vicinity, are remnants of this type. Megalocery in neck-humped as well as in chest-humped sanga breeds offers therefore additional evidence of the share of humpless Hamitic cattle in their evolution.

The reasons for the artificial selection and propagation of inheritable horn gigantism in cattle are social and ritual rather than economic, and are connected with the cattle complex of the pastoral peoples of Africa (Epstein, 1955b). This may still be observed among the Masai and several other pastoral tribes of East Africa. In Tanganyika short-horned zebus are encountered in addition to giant-horned Ankole sanga cattle. Economically, the zebu is definitely the more useful animal; harder, maturing earlier, milking better, working better, and furnishing a superior carcass. It maintains its condition when feed is scarce and innutritious, and water available only every other day. But the owner of an Ankole beast judges altogether differently. He will not exchange a giant-horned Ankole cow of poor conformation and production for a better but shorter-horned zebu. In some parts of Africa, as in the Belgian Congo, the interest of the pastoralists in gigantic horns in their cattle is so great that occasionally horn growth is intensified by irritation of the horn buds. Comparative study has suggested that the cattle complex of the pastoral peoples of East Africa developed farther north among the Hamitic Galla of Ethiopia, and has been carried south by the advances of Nilo-Hamitic cattle breeders (Forde, 1934).

With this we have not exhausted the subject of megalocery in the sanga cattle. Duerst (1926, 1931) presents an entirely different theory as to its causes, considering these to be environmental. Originally he held the climate and humidity of the air in the lake district of Africa responsible; but subsequently he ascribed megalocery to the lack of phosphate and a high degree of acidity in the soil. These are believed to cause acidosis in the organism, resulting in an increased production of horn substance through hyperæmia and hypertrophy of the horn epidermis, associated with a blood supply of insufficient alkalinity and enhanced by the effects of endocrine secretion (Duerst, 1926).

A theory that completely excludes the hereditary disposition to megaloceraty is unacceptable. For it offers no explanation of the occurrence of giant-horned, long-horned, short-horned and polled cattle in the same area, the same herd, even the same family. It offers no explanation of the facts that herds of giant-horned sanga cattle are maintained under widely differing environmental conditions, and that in districts where the giant-horned sanga is replaced by short-horned zebu cattle the latter do not commence to grow gigantic horns. Nor does it offer an explanation of the fact that megaloceraty in sanga herds can be maintained only by continuous careful selection of giant-horned breeding stock.

For these reasons megaloceraty in sanga cattle should be regarded as a hereditary feature. This does not exclude the possibility of its endocrine basis. It appears, however, that Duerst (1926, 1931), while conceding the connection between megaloceraty and endocrine constitution, considers the latter, as far as horn gigantism is concerned, to be dominated by feeding and environment rather than by hereditary factors.

Environment undoubtedly does influence horn development in cattle. It influences horn development along with the skin, hair and bone, along with the whole endocrine constitution of the animal, with the entire physiological and conformational complex.

We have to distinguish between two different types of megaloceraty: one induced by environment, leading to acidosis of the organism, the other independent of environment. In the giant-horned sanga cattle the principal factor involved is not natural environment but artificial selection of an inheritable disposition over a very long period of time. Probably megaloceraty in African longhorn cattle originally occurred only sporadically and not in its present extreme forms. The selection of animals with the largest horns for breeding purposes propagated this feature and created the present giant-horned breeds.

That the giant-horned sanga is merely a variation of the long-horned sanga is readily seen from a comparison of their skulls. Cranially the giant-horned, Bechuana and Bahima cattle are distinguishable from long-horned sanga breeds by little more than the gigantic horn necks and their effect on the conformation of the neurocranium.

In bodily size sanga cattle vary from dwarfed (Mashona) to large-bodied animals (Bechuana). They are, as a rule, well covered, as could be expected from a cross of zebu and Hamitic longhorn cattle (Bisschop, 1937).

The majority of the sanga cattle have well developed dewlaps, similar to those of zebu cattle; but some breeds have small dewlaps, more like those in humpless longhorn cattle. The hind quarters vary considerably. Breeds with a larger share of zebu blood show the typical sloping rump, the low-set pin bones, rounded upper thighs and long narrow gaskins of the zebu; others with a preponderance of humpless longhorn blood exhibit the straighter rump and better let-down thighs of their longhorn ancestors.

The presence of humpless longhorn blood in the sanga may be indicated also by a physiological phenomenon. The longhorn cattle of Egypt seem to have lacked hardiness, which may have contributed to their eventual replacement by a more adaptable type. This physiological weakness has apparently been inherited by some of the sanga cattle. In Uganda, in 1935, Carmichael (1939) diagnosed bovine tuberculosis in 33.3 per cent of the carcasses of Ankole sanga cattle as against 0.6 per cent in those of zebu cattle. Bahima (Ankole) cattle grow weak and perish when taken from their fertile and healthy highland pastures into an inferior environment. Here the sanga cattle cannot compete with the zebu, and their owner's reluctance to part with their giant-horned stock is of no avail. Thus the Bahima between Lake Albert and the northern shore of Lake Victoria now no longer possess giant-horned sanga cattle but breed short-horned zebus. Bahima pastoralists, who had moved with their giant-horned herds into the vicinity of Tabora, were found a few years later in possession of zebu cattle only (Adametz, 1894). As zebus in general are distinguished by a high degree of adaptability to tropical and subtropical environments, the lack of resistance characteristic of many sanga breeds may reasonably be suspected to be a heritage of their humpless longhorn parent stock.

Referring to this physiological factor, Bisschop (1937) remarks that "the question of blood ratio in the sanga is a very difficult one to answer. In size and in general resistance the sanga sub-types vary considerably, but it is suggested that this is due, not so much to blood ratio, as to natural selection and adaptation to the very different environmental complexes in

which they finally became separate sub-types or breeds. Thus, e.g. the Makalanga cattle have managed to survive under some of the worst conditions in Southern Africa. They are exceptionally hardy cattle, but due to their environment have become dwarfed in comparison to, for instance, the sanga cattle of Beuchuanaland."

Environment undoubtedly is the principal factor in imparting hardiness to livestock. The relative hardiness of the entire zebu group, and the comparatively low degree of resistance generally displayed by the humpless longhorn cattle of Africa, are probably due to the different environmental conditions under which these cattle types were originally evolved. But in the course of time these physiological characteristics have become racial characteristics, the zebu as a group having acquired greater hardiness than the humpless longhorn cattle.

The dating of the evolution of the sanga cattle presents some difficulty. The giant-horned sanga breed of Ruanda-Urundi and the shores of Lake Kivu was introduced by the Bahima from Ethiopia about 300 or 400 years ago (Leplac, 1926). From this relatively recent migration it should, however, not be inferred that all sanga cattle now found in East and South Africa arrived at their present breeding grounds merely a few centuries ago. Sir Harry Johnston suggested that the first Bantu invasion from across the Zambesi took place about A.D. 700. From the time the first Bantu tribes left their original home in Central East Africa on their southward migration, many years may have passed until their vanguard crossed the Zambesi. If Johnston's dating of the early Bantu invasions across the Zambesi be accepted, the first Bantu groups must have departed from Central East Africa not much later than the middle of the first millenium A.D. They were then already in possession of herds and flocks and an old pastoral and agricultural tradition. They were not nomads, as the Hottentot hordes, but settled cattle folk and hoe-cultivators—nomad only when compelled to look for new pasture grounds for their stock. Their racial evolution from a mixture of Hamitic and Negro elements, and the evolution of their cultural pattern from a combination of pastoral and agricultural elements, must have occurred centuries before their departure from their East African homes. Apparently it was during this early period of their history that they received their sanga

cattle, which accompanied them on their subsequent migrations.

That the giant-horned sanga cattle of the eastern part of the Belgian Congo were introduced by the Bahima from Ethiopia only 300 or 400 years ago may nevertheless be correct. The Bahima belonged to one of the recent waves of pastoral folk with a Hamatic element, forced to leave their homes in the highlands of Ethiopia in search of new pastures—far more recent than those incoming waves of Hamitic race and culture which, mixing with the Negro, originally gave rise to the Bantu (Seligman, 1930).

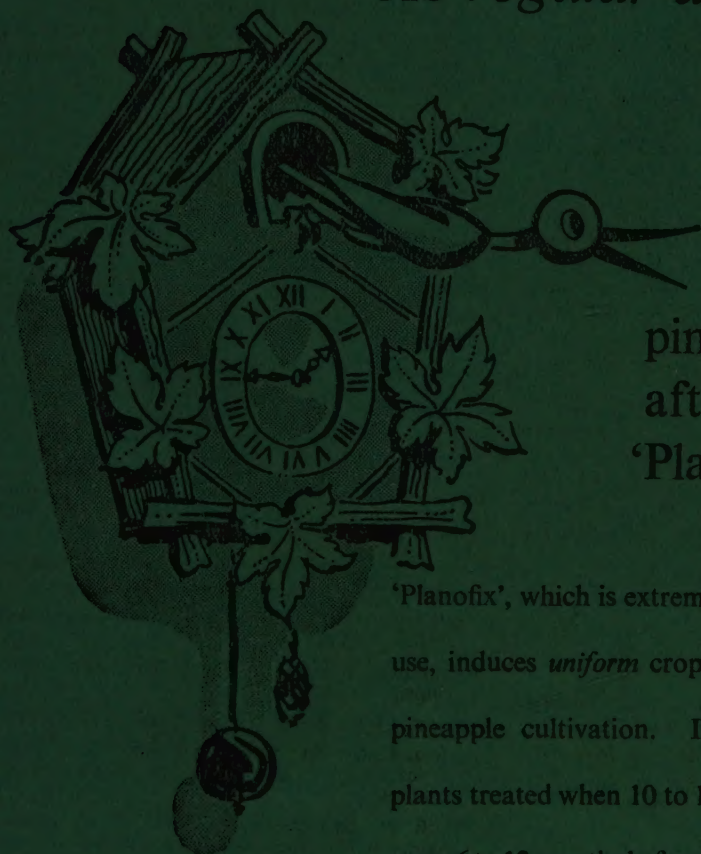
We have to regard the evolution of the sanga breeds, not as a solitary phenomenon during an isolated period of history, but as a prolonged process that occurred first in Ethiopia and the Horn of Africa, and subsequently in all those parts of the continent where neck-humped or chest-humped zebu cattle came into contact with humpless long-horned or giant-horned stock or with sanga cattle previously evolved from a mixture of humpless long-horned or giant-horned and humped zebu stocks. We have to consider the evolution of the sanga breeds as a process that began with the first importation of zebu cattle into Africa approximately 3,500 years ago, and continues with the extension of the range of the zebu in Africa to this day.

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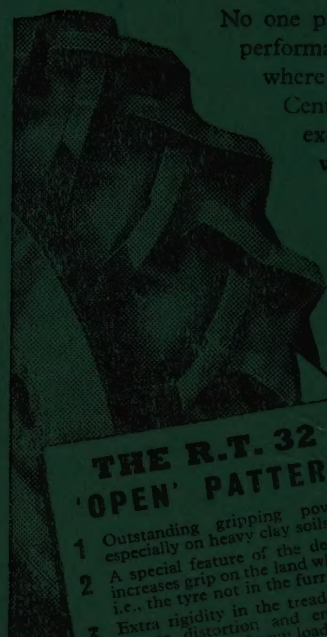
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